VOLUME XV January, 1926 NUMBER 1

FEB 12 1926

[FOUNDED IN 1906 AS THE AMERICAN QUARTERLY OF ROENTGENOLOGY]

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

OFFICIAL ORGAN
THE AMERICAN ROENTGEN RAY SOCIETY
THE AMERICAN RADIUM SOCIETY

Editor: ARTHUR C. CHRISTIE, M.D.

EDITORIAL BOARD

JAMES T. CASE, M.D. H. K. PANCOAST, M.D. WILLIAM DUANE, PH.D.

ADVISORY BOARD FOR PATHOLOGY

JAMES EWING, M.D. Cornell University
EUGENE L. OPIE, M.D. University of Pennsylvania
ALDRED S. WARTHIN, M.D. University of Michigan

PUBLISHED MONTHLY FOR THE AMERICAN ROENTGEN RAY SOCIETY
BY PAUL B. HOEBER, INC., 67-69 EAST 59TH STREET, NEW YORK CITY

AMERICAN ROENTGEN RAY SOCIETY MEETINGS

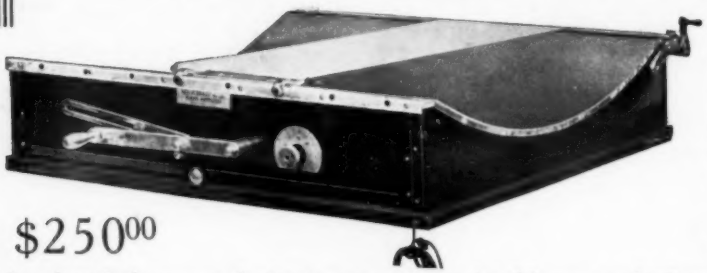
Twenty-Seventh Annual Meeting

BOOK-CADILLAC HOTEL, DETROIT, MICH.

MAY 18, 19, 20 AND 21, 1926

Entered as second-class matter, March 3, 1916, at the Post Office, New York, N. Y., under the Act of March 3, 1879.
YEARLY SUBSCRIPTION, $10.00 INDEX NUMBER SINGLE NUMBERS. $1.50

BRADY'S POTTER-BUCKY DIAPHRAGM



$250.00

NEW FEATURES

A new and improved type of grid construction that secures even more brilliant results than our previous grid.

A neat compression band attachment for holding the patient still during exposure.

Patient brought nearer to plate.

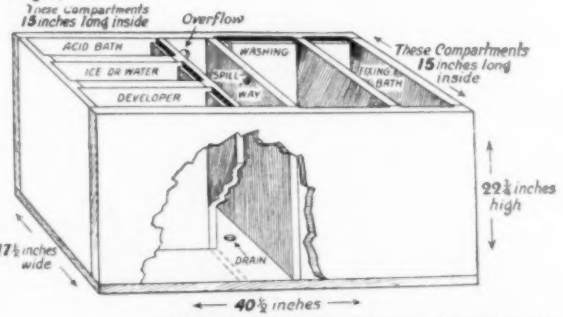
An electrical contact device for operating a signal lamp or which can be connected to most time switches for making the exposure automatically, from 1 to 90 seconds time at $5.00 extra charge.

Our speed control is accurate and reliable and timed in actual seconds. It does not require constant repairs. We claim it is the smallest, neatest and most effective Bucky on the market, 6:1 ratio grid cutting off practically 90% of secondary. Takes all makes of cassettes to 17 x 17 size, operates in horizontal or vertical position, and does Stereoscopic work in either direction.

All-metal construction electrically welded and practically indestructible. They do not get "out of date." Price $250.00 list with cash discount for quck payment.

DEVELOPING TANKS

Our stone tanks are considered the best designs and values on the market. Each has a space for ice or hot water for controlling the developing temperature. The 5 and 6 compartment styles also have a 4" air space to prevent temperature of wash water from affecting the temperature of developer. Lengths over all 24½"-34"-40¼" respectively. Illustration shows our regular 6 compartment style. Special styles to order. We have many sizes of enamel tanks also. Send for special circular.



	4-compartment	5-compartment	6-compartmen
Prices shipped from Virginia	$45.00	$53.50	$60.00
Prices shipped from Chicago, Boston or Brooklyn	$50.00	$58.50	$65.00

DR. GRANGER'S SINUS MASK

For radiography of the sphenoid, etc., at 17° angle. We furnish these to fit all standard makes of cassettes. Specify outside size of your cassette when ordering. Made for 8 x 10 only. Price $8.50.

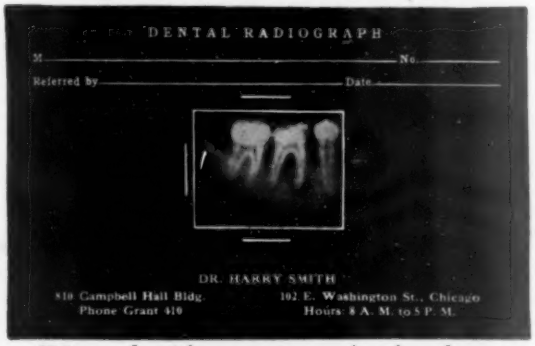
INTENSIFYING SCREENS

Get our net prices on screens either alone, or mounted in cassettes. It may save you some money. We are distributors on Buck X-Ograph cassettes, and carry the standard makes of screens.

BARIUM SULPHATE (Paragon)

We have furnished enormous quantities of this to the profession during the last 10 years. We are prepared to furnish this in prepared form with malted milk or dry milk incorporated at $30.00 per 100 lbs. packed in 25 lb. sealed tin cans. 5 lb. & 10 lb. sizes also available. Price of regular barium $24.00, fluffy style $26.00 per hundred.

DENTAL FILM MOUNTS



We can furnish many sizes and styles of mounts in cardboard or the all-celluloid types. Special designs if desired. Very liberal discounts are allowed on orders for 100 or more. Get our new price list #160—with discounts.

Special on gross lots of #1 size film $6.96.

ASK FOR OUR LATEST PRICE LIST AND DISCOUNTS

GEO. W. BRADY & CO., 761 S. WESTERN AVE., CHICAGO

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

VOL. XV JANUARY, 1926 No. 1

DOSAGE STUDY RELATIVE TO THE THERAPEUTIC USE OF UNFILTERED RADON*

From the Research Laboratories of Memorial Hospital, New York City

I. INTRODUCTION
By G. Failla, D.SC.

II. ANIMAL EXPERIMENTS
By Frank Adair, M.D.

III. SKIN ERYTHEMA DOSES
By Edith H. Quimby, M.A.

IV. BUTTER EXPERIMENTS
By Kanematsu Sugiura, DM.SC.†

V. DISCUSSION OF RESULTS
By G. Failla, D.SC.

VI. PRACTICAL APPLICATIONS
By G. Failla, D.SC., John C. Arnell and Norris W. Goldsmith, B.A.

I. INTRODUCTION

In the process of disintegration of radium a radioactive gas is produced which has been known as radium emanation. In 1923 the International Committee on Chemical Elements suggested the name "radon" for this gas. Accordingly we shall use this term in the present paper.

Two of the disintegration products of radon, radium B, and radium C, emit beta and gamma rays, which are the radiations extensively used in radium therapy. On this account radon may be used in place of radium for therapeutic purposes. Being a gas, it can be sealed in small capillary glass tubes, thus making it possible to use smaller containers. Furthermore, on account of the fact that it disintegrates fairly rapidly, capillary tubes containing small amounts of radon can be inserted into a tumor and left there permanently. This method has been found to be very effective for the treatment of certain types of neoplasm, especially in the mouth, but its use has been limited to a few institutions where radon has been available. The establishment of several plants for the sale of radon, however, has made this substance available to the profession in general, and its use is extending rapidly. On this account the problem of dosage when this method is employed has acquired added importance. Three or four years ago we planned certain experiments for the purpose of obtaining quantitative data bearing on this problem, and we now wish to report the results of our work. In order to make a coherent presentation of the different experiments, however, we shall give first a brief analysis of the problem.

The tubes for permanent insertion into a tumor (variously called "bare tubes," "seeds," "spiculae," "needle points," etc.) are very small in size, ranging from 3 to 4 mm. in length and from 0.3 to 0.4 mm. in diameter. For our present discussion, therefore, we may consider them as point sources of radiation. Making use of the inverse square law, then, we calculate what the radiation intensity is at different distances from the source when there is no matter present to absorb some of the rays. The values thus obtained are shown in column D of Table 1.

Since the wall thickness of the glass tubes containing the radioactive material is very small—about 0.1 mm.—the radia-

* A Leonard Prize paper; read at the Twenty-sixth Annual Meeting, American Roentgen Ray Society, Washington, D. C., Sept. 22–25, 1925.

† From the Harriman Research Laboratory, Roosevelt Hospital, New York City.

TABLE I

CALCULATED PERCENTAGE OF INTENSITY OF RADIATION AT DIFFERENT DISTANCES FROM RADON TUBE

A	B	C	D	E	F
Mm. from Center of Tube-P	Mm. from Outside of Tube-p	$1/P^2$	Per Cent Intensity Due to Inverse Square Law	Per Cent Radiation Transmitted by P. Mm. Tissue	Per Cent Intensity P. Mm. from Center of Tube
0.2	0	25.0	100	100	100
1	0.8	1.0	4.00	48.9	1.96
2	1.8	0.25	1.00	25.4	0.254
3	2.8	0.111	0.444	19.1	0.0848
4	3.8	0.0625	0.250	14.1	0.0353
5	4.8	0.0400	0.160	10.1	0.0162
7	6.8	0.0204	0.0818	8.52	0.00697
10	9.8	0.0100	0.0400	7.52	0.00301
15	14.8	0.00444	0.0178	6.85	0.00122
20	19.8	0.00250	0.0100	6.41	0.00064

tion emitted is largely of the beta ray type, and is easily absorbed by tissue. The figures of column E, Table 1, give the relative amounts of radiation transmitted through different thicknesses of tissue, as determined by ionization measurements. Combining the effect of distance and the absorption of the radiation by tissue we get the figures of column F, which represent the relative values of the radiation at different distances from the tube in the tissue in which it is embedded.

In this calculation we have not taken account of the scattered and secondary radiations which are produced in the tissue and which tend to increase the radiation at the points considered. It will be seen from what follows that for the present discussion this omission is of no serious consequence.

When a tube of radon is left permanently in a tissue, the latter is irradiated at a decreasing rate as time increases, on account of the disintegration of the radon.

Table II shows the amount of radon remaining on successive days in a tube initially one millicurie in value. This of course, does not affect the *relative* distribution of the radiation in the tissue, which is independent of the strength of the radioactive source. Thus, considering

TABLE II

DECREASE OF STRENGTH OF RADON TUBE WITH TIME

Days	Millicuries	Days	Millicuries
0	1.00	9	0.20
1	0.84	10	0.17
2	0.70	11	0.14
3	0.58	12	0.12
4	0.49	13	0.096
5	0.41	14	0.080
6	0.34	15	0.067
7	0.28	25	0.011
8	0.24		

two points in the tissue so situated that one receives ten times as much radiation as the other, we find that this ratio is maintained throughout the life of the radon. On the other hand, the *absolute* amount of radiation reaching different points in the tissue depends on the strength of the source, other conditions being equal.

In order that a perceptible effect be produced in a tissue by radiation which is inherently capable of influencing it, two essential conditions must be fulfilled: (1) A certain minimum *quantity* of radiation must be absorbed by the tissue, and (2) the *rate* at which the radiation is administered to the tissue must be above a certain minimum value. For, if the radiation intensity is sufficiently low, the tissue may be irradiated indefinitely without showing any perceptible change. The minimum amount and rate of administration of radiation depend on the quality of the radiation, on the biological properties of the tissue, on the type of effect to be produced, and on some other factors.

Let us consider one type of tissue under the same conditions, and attempt to determine on the basis of the foregoing considerations, how a definite effect would extend around tubes of different radon content from day to day. We shall assume as a first approximation that the radiation absorbed by the tissue at different distances from the tube is always the same percentage of the amount reaching the point in question. Accordingly we can take the figures of Table 1 to represent also the variation with distance of the relative amounts of radiation absorbed by a very thin slab of tissue. For the present we shall assume also that the biological effect produced by the radiation is independent of the rate

at which the radiation is administered to the tissue. Under these conditions we have

$$Q_x = kI_x \times T \times R_{av}$$

where Q_x = quantity of radiation absorbed by an elemental volume of tissue at distance x from the center of the source;

I_x = radiation intensity at distance x;

T = duration of irradiation in hours;

R_{av} = average value of radon in millicuries during time T;

k = a constant.

Since $T \times R_{av}$ = mc-hr. (millicurie-hours), we have

$$Q_x = kI_x \text{ (mc-hr.)}$$

Let us say now that by experiment we have found the particular effect we are considering to extend to a distance of 3 mm. from the center of the source of radiation when 1 mc. of radon is left in the tissue for 5 days. The millicurie-hours in this case will be 79, and the value of I_x for x = 3 mm. is 0.085 according to Table 1. Hence

$$Q_3 = k \times 0.085 \times 79 = 6.7k$$

The fact that the effect was limited to a distance of 3 mm. indicates that the radiation reaching beyond this point was insufficient to produce the same tissue changes. Accordingly 6.7k is the minimum quantity of radiation necessary to produce the visible effect under consideration. For comparative purposes we can take the constant k as equal to one. Whence

$$Q_{min} = Q_3 = 6.7 \text{ arbitrary units.}$$

It is evident that if the radon is left in the tissue for a longer time, or a stronger source is used, the minimum quantity of radiation required to affect the tissue will be delivered at a greater distance. The data developed so far enable us to calculate the radius of action of the radiation for different durations of irradiation and different initial values of the source, subject to the assumptions we have made. The procedure is as follows: we have

$$Q_x = I_x \text{ (mc-hr.)} = 6.7$$

or

$$I_x = \frac{6.7}{\text{mc-hr.}}$$

Assigning different values to mc-hr. we determine the corresponding values of I_x. Then referring to Table 1 we find the values of x corresponding to each value of I_x.* This gives the distance in the tissue at which the minimum necessary radiation is available under the different conditions. According to our premises this corresponds to the distance to which the particular radiation effect would extend. The results are given in graphical form in Figures 1 and 2.

It will be seen that: (1) The radius of the affected region increases very rapidly during the first day for all the millicurie values given. (2) The increase becomes gradually less marked after the first day, and on the fifth day the radius is only slightly smaller than the maximum possible value. The maxima corresponding to the time of complete extinction of the radon are given along the line MM. (3) For equal time intervals, the stronger the radioactive source is, the larger is the radius of action.

These results are based on certain assumptions and therefore it is important to examine how they would be affected by deviations from these assumptions. Thus in practice, (1) the source is not a point, but a tube about 4 mm. long. On this account the increase in the radius would be less rapid during the first two or three days, and the difference would depend on the strength of the source. (2) The scattered and secondary radiations are not negligible. The effect of their presence would be to increase the radius for the same time interval for each millicurie value. (3) There is a minimum rate of administration of radiation below which the tissue would not show the change in question. This would decrease the maximum radius of action for each tube. (4) In the case under discussion, where beta and gamma rays are involved, there is no direct correspondence between the radiation intensity as measured by an ionization instrument, and the amount absorbed by tissue. Furthermore, we can-

* For this purpose the values of Table 1 were plotted to a large scale so that no interpolation was necessary.

not say that the biological effect is dependent on the absorbed radiation, irrespective of its type and quality. The available information on this point[1] suggests that beta radiation is more effective biologically than ionization measurements would indicate it to be. Accordingly the increase in the radius of action with respect to time and millicurie value should be more rapid in the portion of the path where beta radiation plays a predominant part. (5)

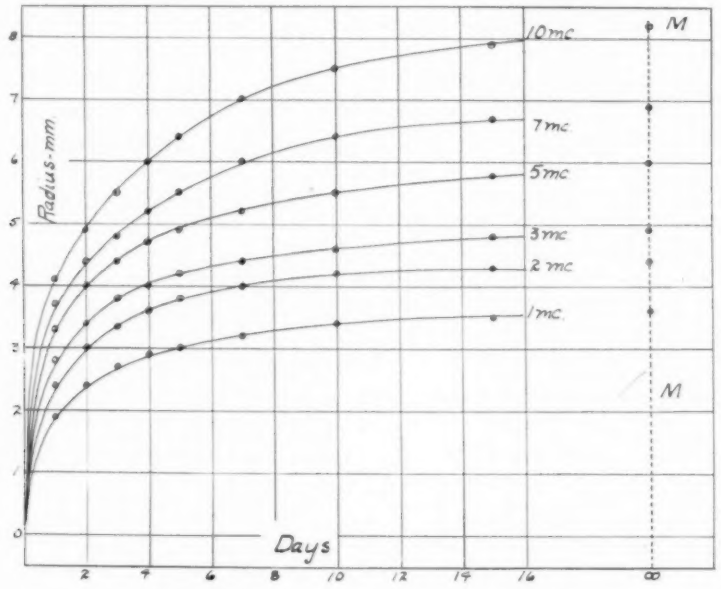


FIG. 1. Variation in affected area with time.

We must consider also the effect of the repair process which will be going on in the living tissue. This will have a tendency to decrease the radius of action. (6) We have not taken into account the latent period

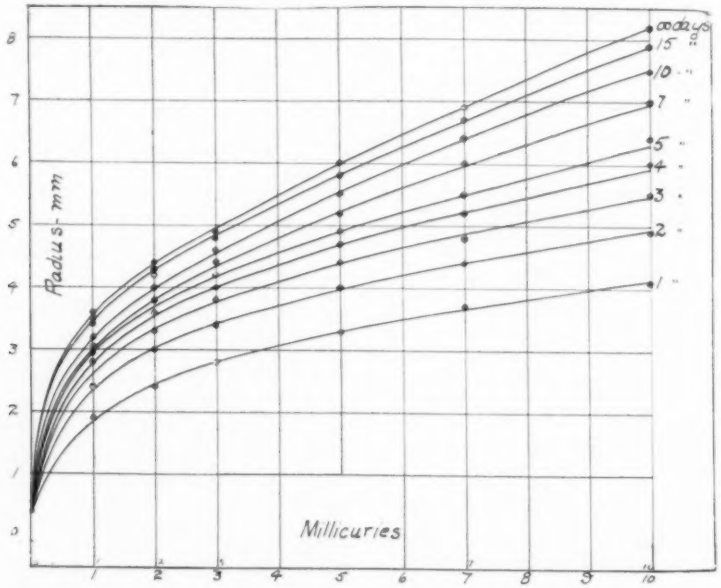


FIG. 2. Variation in affected area with initial tube strength.

in the biological action of radiation and its variation with the tissue change considered and the quality of the radiation which produces it. (7) Finally we should remember that the calculated radii are all relative to an assumed tissue change extending to a distance of 3 mm. when a tube of 1 mc. is used for five days.

From the preceding discussion it is evident that the information embodied in Figures 1 and 2 is only qualitative. Since for dosage purposes quantitative data must be available, additional experimental information is required. The foregoing analysis of the problem has served to point out the different factors which enter into it, and we are now in a better position to discuss the experiments intended to supply the missing data.

It will be noted that the most important assumptions we had to make before, referred to the effect produced in living tissue by the radiations. Accordingly only biological experiments can supply this information. The experiments which we carried out for this purpose will be described in a separate section of this paper. Suffice it to say here that they were planned with the idea of getting quantitative data correlating the strength of the source and the duration of the irradiation with the extent of the tissue changes.

Before undertaking the above work, it was known qualitatively[2, 3, 4] that a radon tube buried in living tissue for a certain time, produced intense necrosis immediately around it, and that beyond this there was a region in which marked radiation changes could be observed by histological examination. Having planned experiments to determine with some degree of precision the extent of the tissue changes with different amounts of radon and different time intervals, it appeared to us of considerable importance to determine also the radiation dose at different points in the irradiated tissue which was responsible for the observed changes. This would enable us to correlate cause and effect more directly and would supply more valuable data for dosage purposes.

We realized at the outset that the measurement by physical means of the dose at different points in the tissue would be subject to large errors, and therefore we adopted a different course. The experiments will be described in a separate section, but we may say here that the method used enables us to express the doses in terms of a skin erythema unit.

On account of the fact that biological experiments are difficult to carry out if quantitative data are desired, we thought it would be very desirable to find some means whereby information about the extent of the radiation effects in tissue could be determined from simple experiments. Knowing that radium rays have the property of changing the color of many substances, especially organic compounds, we directed our efforts in this direction. The plan was to put a radon tube in the material and observe the change in color from time to time. Many substances having about the same density as average human tissue were tried, but, for one reason or another, they were found unsuitable. In the meantime one of us was investigating the effect of radium rays on butter for a different purpose, and found that the change in color here was quite marked and distinct. We therefore concluded that butter was a suitable medium to use for the purpose we had in mind. The experiments and the results obtained are described in the fourth section of this paper.

Recapitulation. We have seen how by physical experiments alone it is impossible to predict with reasonable precision the radius of action of a given tube of radon embedded in a given tissue for a definite length of time. For this reason animal experiments were planned to supply quantitative data subject to certain definite conditions. Other biological experiments were planned to supply information as to the dose of effective radiation delivered to different points of the tissue. The results of these two sets of experiments can then be combined, thus giving us a correlation between dose and effect which makes possible a more general application of the data to the problem of dosage. A simple method is given whereby one can obtain a visual picture of the effectiveness of radon tubes buried in tissue, without the necessity of animal experiments. Fi-

nally we shall combine all the results to determine the proper distribution of radon tubes in tumors of different sizes.

II. ANIMAL EXPERIMENTS

The discussion in the first part of the paper has shown the necessity of carrying out experiments with living tissue to determine the radius of action of radon tubes under varying conditions. Since in doing this work the object in view is to obtain data which can be used for dosage purposes in radium therapy, it is evidently desirable to use tumor tissue as the experimental medium. Obviously, however, human tumors could not be used to experiment upon. Animal tumors, on the other hand, might react to the radiation quite differently from human tumors, and differently among themselves. In addition, retrogression of the tumor due to the radiation would complicate results. It was decided, therefore, to use normal muscle tissue, which could be duplicated with a fair degree of certainty. It was found after some preliminary tests, that the lumbar muscles of the rabbit are very satisfactory for such experiments. They are relatively large, measuring about 9 cm. in length, 2 to 2.5 cm. in thickness, and 3 cm. in width. The tissue is also very homogeneous, although it is not isotropic.

The experimental procedure was as follows: Having prepared a number of radon tubes, 11 mm. long, and approximately 0.5 mm. in diameter, each was measured carefully by means of a properly calibrated electroscope. The millicurie value of each tube, therefore, was known within 0.5 per cent. Each tube was then washed in xylol, to remove any paraffin which might have adhered to it; the tube was sterilized in alcohol, and then placed in sterile water. A steel needle and trocar, of the type ordinarily used for the insertion of the tubes into a tumor, was also sterilized in 70 per cent alcohol, and then washed in sterile water. This precaution was taken to eliminate the possibility of tissue changes due to the introduction of any alcohol.

The hair overlying the lumbar region of the rabbit was shaved, and 7 per cent iodine applied just caudally to the ilium. Using sterile forceps, the radon tube was placed in the needle, the plunger having been previously withdrawn a sufficient distance. The needle was then inserted into the lumbar muscle at a point near the crest of the ilium, and pushed forward, a little short of the center of the muscle. By pushing home the plunger, or stylet of the needle, the tube was thus discharged into the muscle substance close to the geometrical center. During this process it was necessary to have a competent assistant, because if the rabbit moved its body sidewise, the tube might be deposited too near the transverse processes of the spine, or too near the outer edge of the muscle.

The tubes remained in the muscle for different time intervals, varying from twenty-four hours to four weeks. At the end of the desired period, the rabbit was sacrificed by a blow on the neck, so as not to disturb in any way the local factors of the experiment. Within three minutes from this time the entire lumbar muscle was removed, thus obviating the possibility of any effect of the radiation after the death of the animal. While the muscle was still capable of contraction, it was held in front of a strong light, and from this examination, the location of the tube was ascertained. Then with a sharp razor blade an incision was made down to the tube, as nearly at right angles to it as possible. By means of a pair of fine forceps, the tube was carefully removed after bending the cut half of the muscle. This permitted the completion of the incision through the lower half of the muscle specimen. Great care was exercised to make sure that the section was perpendicular to the long axis of the tube, and that it divided the tube nearly into two equal parts.

The cross section of the muscle presented a central hole about 0.5 mm. in diameter, at the point where the capillary tube had formerly been. This was surrounded by an approximately circular area of congestion or necrosis, depending on the strength of the tube, and the length of time it had remained *in situ*. The necrotic area, especially in the case of the stronger tubes, was surrounded by a zone of congestion.

TABLE III

DATA FROM ANIMAL EXPERIMENTS

No. of Exp.	A Initial Millicuries	B Days	C Actual Mc.-hr.	D Radius Mm. Inner	E Radius Mm. Outer	F Probable Error in D ±Mm.
A6	30.42	7	2894	8.05	9.25	
A5	30.0	4	2045	6.50	8.95	
A4	26.9	3	1495	5.55	8.3	
A2	25.7	2	1035	4.55		
Average..	**28.2**		**1867**	**6.16**	**8.83**	±0.50
E2	10.8	6	950	5.6	5.75	
E1	11.03	4	754	5.15	5.45	
Average..	**10.9**		**852**	**5.38**	**5.60**	±0.15
D2	9.91	4	672	5.1	5.95	
B2	9.56	4	654	4.6	6.75	
B4	9.46	6	827	4.25	5.35	
C2	9.04	6	788	6.6	6.68	
Average..	**9.49**		**735**	**5.14**	**6.43**	±0.37
E1	8.99	4	614	5.2	5.5	
B5	8.95	8	910	5.55	5.9	
E2	8.94	6	786	5.05	6.1	
D1	8.89	6	778	5.3	5.95	
F4	8.82	8	891	5.2		
C1	8.72	4	594	5.05	5.6	
C1	8.72	4	594	5.15	5.65	
F3	8.54	6	754	5.45	5.95	
F3	8.44	6	746		5.4	
F2	8.18	5	648		5.7	
E3	8.06	6	708	5.7	5.9	
Average..	**8.66**		**730**	**5.30**	**5.74**	±0.05
F1	7.93	4	543	4.25	5.0	
E3	7.89	6	694	5.35		
D2	7.87	4	538	4.7	5.45	
B3	7.84	5	621	4.1	4.95	
G1	7.54	7	719	4.65		
F4	7.46	8	759	4.9		
G1	7.42	7	707	5.4		
C2	7.13	6	622	5.15		
Average..	**7.61**		**650**	**4.81**	**5.13**	±0.10
O7	3.68	7	352	4.35		
O7	3.65	7	349	4.4		
O4	3.64	7	348	4.8		
O4	3.58	7	342	5.25		
O1	3.51	4	240	4.15		
O1	3.44	4	236	4.1		
O2	3.38	4	231	4.25		
O5	3.34	7	320	5.0		
M2	3.33	6	293	4.7		
O6	3.31	7	317	4.9		
O2	3.30	4	226	4.3		
N1	3.25	4	222	3.65		
N1	3.25	4	222	4.0		
O3	3.23	4	221	4.7		
O5	3.21	7	307	4.55		
M1	3.20	6	282	4.55		
N3	3.10	4	212	3.65		
N3	3.10	4	212	3.65		
O3	3.08	4	210	5.05		
N5	3.05	7	291	4.25		
O6	3.03	7	289	4.85		
N5	3.02	7	288	4.0		
M1	3.00	6	265	5.0		
N6	2.97	7	284	4.45		
N6	2.97	7	284	4.3		
Average..	**3.26**		**274**	**4.42**		±0.06
B5	1.56	8	159	2.7	2.8	
B4	1.50	6	132	2.65	3.1	
H3	1.34	6	118	2.35		
B2	1.30	4	89	2.2	3.3	
H2	1.29	6	114	2.8	3.25	
Average..	**1.39**		**122**	**2.54**	**3.11**	±0.07
L7	1.23	7	118	2.55		
L6	1.21	7	116	3.35		
H2	1.20	6	106	3.25		
L7	1.17	7	112	2.7		
H1	1.17	6	103	3.5		
H1	1.16	6	102	3.15		
H3	1.14	6	100	2.55		
I2	1.12	7	107	2.7		
L4	1.12	7	107	3.0		
Average..	**1.17**		**108**	**3.03**		±0.09
L4	1.10	7	105	2.4		
L3	1.09	7	104	2.45		
L3	1.08	7	103	2.45		
H4	1.08	7	103	2.95		
L5	1.06	7	101	3.0		
J2	1.06	4	73	2.85		
J2	1.04	4	72	2.9		
L5	1.02	7	98	2.65		
I3	1.01	7	97	2.85		
I3	1.01	7	97	3.0		
K2	1.01	4	69	3.1		
K2	1.00	4	70	2.65		
L1	1.00	7	96	2.85		
L2	1.00	7	96	2.55		
L2	1.00	7	96	2.55		
J1	1.00	4	69	2.25		
L6	0.99	7	95	2.55		
I1	0.97	7	93	3.05		
K3	0.95	5	75	2.5		
K3	0.95	5	75	2.35		
I1	0.92	7	88	3.0		
J3	0.92	4	63	2.85		
K4	0.91	5	71	2.8		
Average..	**1.05**		**87**	**2.73**	**3.0**	±0.05
P3	0.51	7	48.8	2.45		
P3	0.51	7	48.8	2.3		
P4	0.51	7	48.8	2.35		
P2	0.49	7	46.8	2.15		
P1	0.46	7	44.0	2.65		
P2	0.46	7	44.0	2.1		
Q1	0.46	7	44.0	2.35		
Q1	0.46	7	44.0	2.2		
Q2	0.45	7	43.0	2.15		
Q3	0.45	7	43.0	2.4		
Q3	0.44	7	42.0	2.35		
Q4	0.43	7	41.0	2.2		
Q4	0.42	7	40.2	2.05		
Average..	**0.47**		**44.5**	**2.28**		±0.03
A6	0.42	7	40.2	1.55		
R1	0.42	4	28.9	1.8		
R2	0.39	4	26.8	1.55		
R2	0.39	4	26.8	1.55		
R3	0.38	4	26.1	2.0		
R3	0.38	4	26.1	1.65		
R4	0.38	4	26.1	1.3		
R4	0.37	4	25.4	1.5		
Average..	**0.39**		**28.3**	**1.61**	**2.16**	±0.05

The sharpness of the outline of this congested zone varied with the millicurie value of the tube, and with the duration of the irradiation. Measurements of these gross changes seen by the unaided eye, were made immediately after sectioning the muscle. In this way we obtained the diameter of the necrotic area, and the diameter of the zone of congestion in the fresh tissue, before placing it in a hardening fluid. The diameter was determined by means of a pair of dividers having sharp points, and a millimeter scale. Measurements were made in four different orientations, and then averaged. Values definitely larger or smaller than the average were discarded. In each case the distance between the points of the dividers was determined by difference, to avoid personal bias.

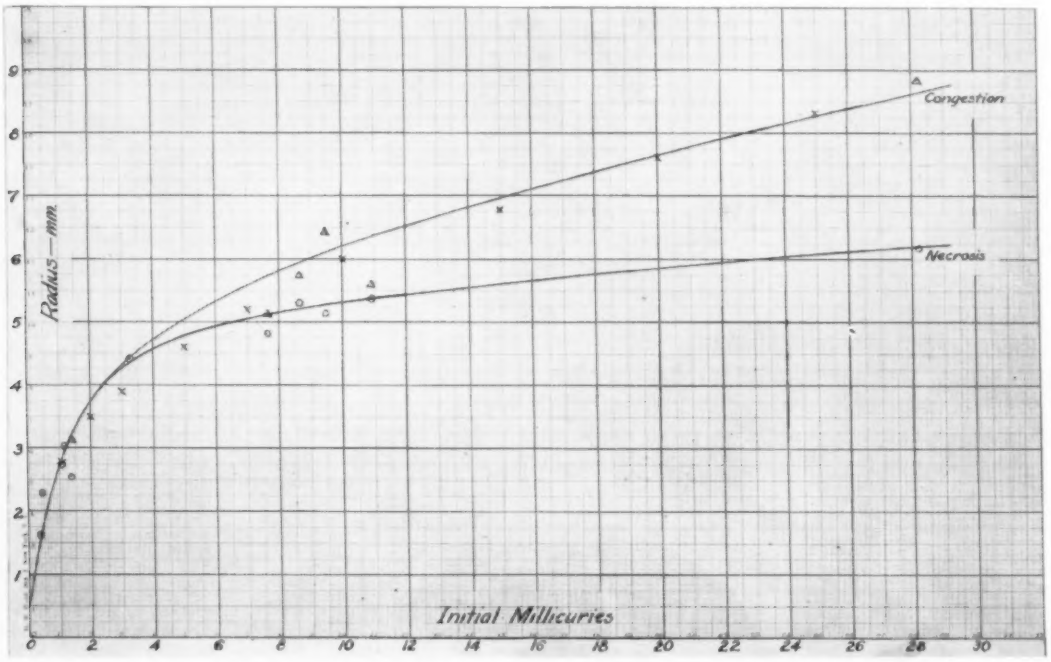


FIG. 3. Variation in zones of necrosis and congestion with initial tube strength.

Results. On account of the fact that in general there is a latent period in the biological action of radiation, and that in living tissue we must consider also the repair process, preliminary experiments were made to determine the time at which the tissue would show the maximum effect. In this series, tubes of nearly equal initial values were used, and the animals were killed at different intervals. It was found that the necrotic area did not increase appreciably after the third or fourth day from the time the tube was inserted into the tissue. To state the case more accurately we should say that there was a considerable variation in the diameters of the necrotic areas, even when tubes of equal strength were used for the same length of time. On this account an increase in the diameter due to a longer exposure, if present, was masked by the fortuitous variations which occurred otherwise. In view of these findings, in the case of the principal experiments the tubes were allowed to stay in the tissue from four to seven days.

The results of these determinations are given in Table III. Averages for each group of approximately equal initial millicurie values are shown in heavy type. The probable error in each case appears in column F. It will be seen that in the case of the weaker tubes, no values are given for the outer radius of the zone of congestion. This is due to the fact that for these tubes the zone of congestion was either missing, or

was so indistinct as to make its measurement impossible. The results are shown graphically in Figure 3, the circles referring to the radius of the necrotic area, and the triangles to the outer radius of the congested zone. The curves represent, as far as the data permit, the most probable variation of the radius of necrosis and the radius of congestion with respect to the initial strength of the radon tube. The justification for using the initial millicuries as one of the coordinates is that the radii do not increase appreciably after about the fourth day, and, therefore, they are more directly related to the strength of the source than to the millicurie-hours (col. C).

It will be seen that the necrotic area increases rapidly for the values of the source up to three or four millicuries, but only slightly for larger values. The zone of congestion appears at about this point, as far as we can judge, and increases relatively more than the area of necrosis.

The histological study of the material obtained from these experiments has not been completed. We can say, however, that marked radiation effects can be observed in the tissue about a millimeter beyond the limit of the necrotic area when weak tubes are used. For the stronger tubes, this region is considerably larger. This would indicate that for therapeutic purposes it is preferable to use the stronger tubes, because a more widespread effect can be produced in the tissue without a proportional increase in the amount of necrosis. However, in practice, many other factors must be taken into account, and the soundness of this conclusion must be determined clinically.

III. SKIN ERYTHEMA DOSES

In the first part of the paper we discussed the desirability of determining the dose of radiation reaching points in the tissue at different distances from the embedded radon tube. We also mentioned the fact that physical means could not be relied upon to measure the dose. It was decided, therefore, to use a biological indicator for this purpose. Having had considerable experience in determining the radiation dose for different degrees of filtration of the radon source, using skin erythema as the unit, we adopted a similar procedure in this case.

The problem was to reproduce as nearly as possible the physical conditions around the radon tube within the tissue, and still be able to use the human skin to determine the effectiveness of the transmitted radiation. If we had a substance which absorbs and scatters radium radiations in the same manner as tissue, it could be used as the medium in which to imbed the tube. Then, by slicing off sections of this medium at different distances from the tube and applying the remaining part over the human skin, we could determine the millicurie-hour dose required to produce an erythema for each distance taken.

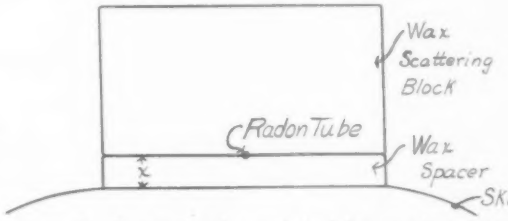


FIG. 4. Applicator for determining skin erythema doses.

The substance to be used as a tissue substitute was found by ionization measurements. Since the components of tissue are largely nitrogen, oxygen, hydrogen, and carbon, the substances tested were of similar constitution. With a suitable electroscope the absorption of radiation was measured in rubber, wood, paraffin, beeswax, cardboard, and celluloid, and compared with the absorption by tissue. The absorbing power of beeswax was found to differ from that of tissue by less than 5 per cent. Accordingly it was used for the tests.

The experiments were performed as follows: Slabs of beeswax were prepared of various thicknesses (x, Fig. 4). The glass tube of radon was attached to one face of one of these, say 1 cm. thick. Above the radon was fastened a large block of wax. The whole mass was then firmly strapped to the patient to be tested. Thus between the skin and the radon tube was 1 cm. of wax, the physical conditions being the same as if the tube were buried 1 cm. deep in the tissue. The dose in millicurie-hours

for each distance was varied until the one producing the threshold erythema was discovered. In every case, the left leg of the patient, just above the knee, was used for the test. On the right leg, in the corresponding location, a standard applicator, for which the dose was accurately known, was used as a control. In this way an abnormal reaction of the skin could be easily detected, and proper allowances made. The results obtained are shown in Table IV.

TABLE IV

SKIN ERYTHEMA DOSES

Wax Filter, Mm.	Erythema Dose Mc-hr.
0.	0.075
2.5	3.0
5.0	8.0
10.0	60.0
15.0	250.0
20.0	800.0

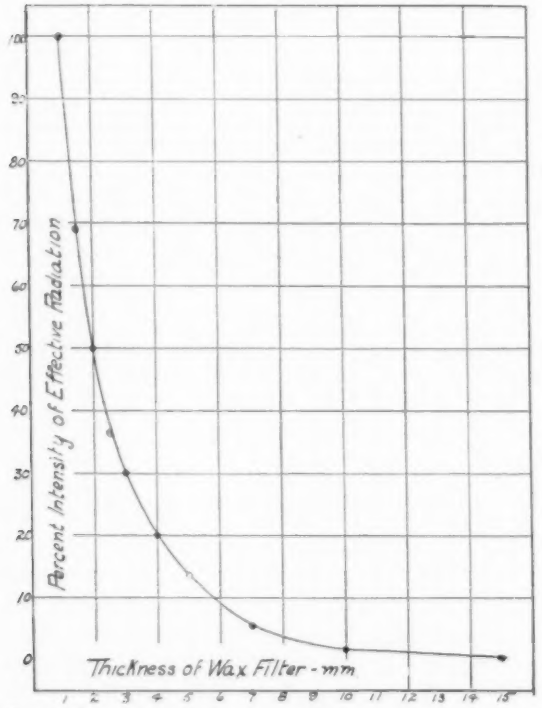


FIG. 5. Intensity of effective radiation in skin erythema doses.

It is important to note that the accuracy of these results depends on the method adopted to judge the skin erythema. The method we use is practically objective, in that the observer does not have to take into account the intensity of the erythema. It is only necessary to determine whether an erythema is or is not present in all the patients treated with the same dose under the same conditions. If it is, then the dose is high, and another series of tests is made with a smaller dose. The process is repeated until a dose is found for which the less radiosensitive patients in the group do not show an erythema, while the others do. This is the threshold erythema dose for the average patient under the conditions of the test. Having made such tests on over one thousand patients during the last four years, we have gained considerable experience in this work, and we feel that the average values given in Table IV are not in error by more than 10 per cent.

Referring to Table IV, we find that, to produce the threshold erythema at a distance of 2.5 mm. from the tube in the wax block, the millicurie-hour dose was 3.0. For a distance of 10 mm. it was 60.0 mc-hr. Hence the radiation effective in producing the erythema in this case must have been $\frac{6}{30} = \frac{1}{20}$, or 20 times less than in the case of the 2.5 mm. distance. In this way it will be seen that the intensity of the effective radiation is inversely proportional to the millicurie-hour doses. The values in Table V have been calculated on this basis, taking the intensity at 1 millimeter distance as 100 per cent. They are shown graphically in Figure 5.

TABLE V

RELATIVE INTENSITY OF RADIATION EFFECTIVE IN PRODUCING SKIN ERYTHEMA

Wax Spacer, Mm.	Dose, Mc-hr.	Intensity, Per Cent
0	0.075	1460
0.25	0.4	276
0.5	0.7	157
1.0	1.1	100
1.5	1.6	68.8
2.0	2.2	50.0
2.5	3.0	36.6
3.0	3.7	29.7
4.0	5.5	20.0
5.0	8.0	13.7
7.0	20.0	5.50
10.0	60.0	1.83
15.0	250.0	0.44
20.0	800.0	0.14

Since the duration of the irradiation has an effect on the dose required to produce an erythema, it should be mentioned here that the length of the treatment in the above tests varied from a few minutes to about four hours. The longer treatments, in general, refer to the longer distances, inasmuch as it was not always possible to use very strong radon tubes, and large doses were required in these cases. From previous experiments, however, we can say that *for the time range used here* there is no large variation in the millicurie-hour dose whether a weak or strong tube is used.

IV. BUTTER EXPERIMENTS

The animal experiments reported in Part II of this paper show how living tissue is affected by the rays from a radon tube buried therein. To obtain this information with reasonable accuracy a larger number of animals had to be used, and the work extended over a long period of time. Calculations based on physical measurements of the radiation are not sufficient to predict the radius of action of the radiation under different conditions. Evidently, then, it would be a decided advantage to have a simple physical or chemical method for studying the action of a radon tube.

Many chemical phenomena might lend themselves to an investigation of this character. For instance, one might use the effect on the photographic plate, the change of color in an iodoform-starch mixture, the bleaching of various vegetable or animal substances, such as beets, carrots, cheese, butter, egg yolk. The inhibition of growth of bacteria in agar, and of yeast in sugar solution might also be utilized. From our point of view the requirements are: (1) The medium should have about the same chemical composition and density as animal tissue, so that the absorption and scattering of the radiation would be nearly the same as in the tissue. (2) The change should be very definite and easily measurable. (3) The reaction should not be influenced by slight changes in laboratory conditions, or other extraneous causes. It is preferable, in addition, that the quantity of radon required to produce the measurable changes be in the neighborhood of the amounts ordinarily used in living tissue. Of the different phenomena and media we tried, the bleaching of butter is the most satisfactory for our purposes. Accordingly a number of experiments were carried out with this substance.

The experimental technique was always the same. Blue Valley butter was used, and the medium was prepared as follows: The butter was melted in a beaker immersed in warm water at about 45°C. The melted butter, after being thoroughly stirred, was poured into Petri dishes so that they were full to the brim. It was left standing for about an hour at room temperature, and then placed in the refrigerator to harden. If foam appeared on the surface of the butter, it was removed with a glass rod before the medium hardened. The dish was kept in the refrigerator throughout the experiments, except for the short time required to make the measurements. The radon tubes used were all of glass, unscreened, and of different sizes and strengths. Each tube was embedded in the butter so that it was flush with the surface. Tubes were placed far enough apart so that the radiation from any one would have no effect on the bleached area surrounding any other.

Shortly after the insertion of the tubes, a light colored area appeared around each. In a few hours the region immediately surrounding the tube was bleached white. This white area increased at first rapidly, then more slowly, and finally became stationary. In the experiments the diameter of this bleached area was measured with dividers from day to day, the recorded observations each being the mean of several readings.

The effect of intensifying the color of the butter with artificial dye, to give greater contrast, was investigated. It was found that this decreased the sensitivity of the medium to the radiation. This might be explained on the basis that a larger amount of coloring matter had to be altered before the change became noticeable. With butter of the usual color it was found that if a very strong tube is used, the material immediately surround-

ing it has a snowy appearance, indicating that all of the coloring matter has been changed.

Tests were made for the possible existence of a latent effect. The size of the bleached area, however, was found to remain unchanged after the tube had been taken away. Even six months later, although the whole surface of the medium had faded somewhat, the bleached areas were distinct, and of the same dimensions.

The following investigations were carried out:

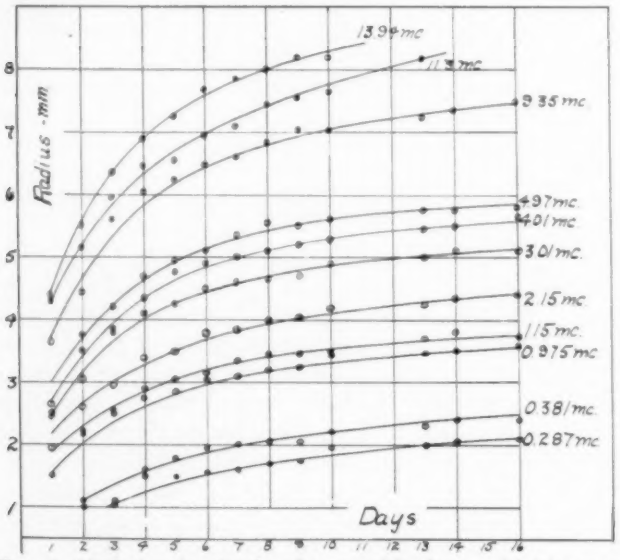


FIG. 6. Variation in discolored area with time and initial tube strength.

1. The variation in bleached area with variation in initial millicurie value of tube,—tube size remaining constant.

2. The variation in bleached area with time, for tubes of different strengths,—tube size remaining constant.

3. The variation in bleached area for the same millicurie-hour irradiation, for tubes of different initial strengths,—tube size remaining constant.

4. The variation in bleached area for variation in tube length,—initial millicuries remaining constant.

5. The variation in bleached area with the addition of a block of scattering material over the butter,—other factors remaining constant.

We shall give now the results of these experiments.

In one series tubes of different radon content, but having very nearly the same dimensions, were used. The length of the capillary tubes was 11 mm., to conform with the length of the tubes used in the rabbit experiments. The change in the discolored area from day to day is shown graphically in Figure 6. It will be seen that for all the tubes the increase is very much more rapid during the first day.

After the eighth or tenth day the area of discoloration increased very little, which is in accordance with what one might expect, considering that in this time the radon in the tubes has decayed to a small percentage of the initial value.

An inspection of the curves suggests the possibility of the existence of a general relation among them. To test this point, values were read from the curves and tabulated (Tables VI and VII).

Then percentages were calculated as shown. It will be seen that the percentages in each column (for the same millicurie value or the same day as the case may be) agree very closely among themselves, except for the weakest tubes. This means that the relative change in the area of discoloration with respect to the strength of the source is the same from day to day. For instance, if a tube of 0.975 mc. gives a radius of 2.72 mm. on the fourth day and 1.15 mc. gives 2.9 mm. on the same day (see Table VI), the ratio between these is 1.06. That is the stronger tube produces an area having a radius 6 per cent larger. On the fifth day the weaker tube gives a radius of 2.92 mm. and the stronger one of 3.10 mm. which is again 6 per cent larger. Similarly for any other day the ratio of the radii of the areas of discoloration produced by these two tubes, in very nearly the same (1.06 to 1.08). It follows, therefore that the radii of discoloration for tubes of different radon content bear the same relation to one another at all times after the fourth or fifth day. The percentages in each column, Table VII (for the same day value) agree*

* This agreement is a necessary consequence of the one previously mentioned.

TABLE VI

VARIATION OF DISCOLORED AREA WITH INITIAL STRENGTH OF TUBE

Time, Days	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent
	0.287 mc.		0.381 mc.		0.975 mc.		1.15 mc.	
4	1.30	48	1.61	59	2.72	100	2.90	106
5	1.48	51	1.81	62	2.92	100	3.10	106
6	1.58	52	1.95	64	3.05	100	3.26	107
7	1.66	53	2.02	65	3.12	100	3.35	107
8	1.72	54	2.08	65	3.18	100	3.42	107
9	1.75	54	2.10	65	3.24	100	3.48	107
10	1.78	56	2.11	65	3.26	100	3.51	108
16	2.10	58	2.40	67	3.60	100	3.75	102
Average		53		64		100		106
	2.15 mc.		3.01 mc.		4.01 mc.		4.97 mc.	
4	3.35	123	4.06	149	4.38	161	4.65	171
5	3.60	123	4.31	148	4.68	160	4.96	170
6	3.78	124	4.49	147	4.88	160	5.19	171
7	3.90	125	4.60	147	5.02	161	5.35	172
8	4.00	125	4.68	147	5.12	161	5.48	172
9	4.05	125	4.74	147	5.20	161	5.56	172
10	4.10	125	4.78	147	5.25	161	5.62	172
16	4.40	122	5.10	142	5.65	157	5.80	161
Average		124		146		160		170
	9.35 mc.		11.3 mc.		13.94 mc.			
4	5.98	220	6.43	236	6.90	254		
5	6.31	216	6.80	233	7.30	250		
6	6.55	215	7.08	232	7.63	250		
7	6.74	216	7.30	234	7.88	252		
8	6.86	216	7.44	234	8.06	254		
9	6.95	214	7.56	233	8.16	252		
10	7.00	215	7.61	232	8.24	252		
16	7.50	208	7.45	222	8.55	237		
Average		215		232		250		

among themselves except again for the weakest tubes, in which case the variation is appreciable. Hence, the relative change in the area of discoloration with respect to the time of exposure is the same for all millicurie values from about 0.3 to 14 mc.

These constant relations enable us to represent all the data in the two tables by two curves. In Figure 7 we have the curve for the increase of the discolored area from day to day for a definite amount of radon (0.975 mc.) in a tube 11 mm. long. The curve of Figure 8 represents the *relative* effect of the strength of the source on the radius of the discoloration for the same length of tube for any day from the fourth to the fifteenth.

TABLE VII

VARIATION OF DISCOLORED AREA WITH TIME OF EXPOSURE

Initial Strength of Tube Mc.	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent
	4 days		5 days		6 days		7 days	
0.287	1.30	100	1.48	113	1.58	122	1.66	128
0.381	1.61	100	1.81	112	1.95	121	2.02	126
0.975	2.72	100	2.92	107	3.05	112	3.12	115
1.15	2.90	100	3.10	107	3.26	112	3.35	115
2.15	3.35	100	3.60	107	3.78	113	3.90	116
3.01	4.06	100	4.31	106	4.49	111	4.60	113
4.01	4.38	100	4.68	107	4.88	111	5.02	115
4.97	4.65	100	4.96	107	5.19	112	5.35	115
9.35	5.98	100	6.31	106	6.55	110	6.74	113
11.30	6.43	100	6.80	107	7.08	110	7.30	114
13.94	6.90	100	7.30	106	7.63	111	7.88	114
Average		100		108		113		116
	8 days		9 days		10 days		16 days	
0.287	1.72	132	1.75	135	1.78	137	2.10	162
0.381	2.08	129	2.10	130	2.11	131	2.40	150
0.975	3.18	117	3.24	119	3.26	120	3.60	132
1.15	3.42	118	3.48	120	3.51	212	3.75	130
2.15	4.00	119	4.05	121	4.10	122	4.40	132
3.01	4.68	115	4.74	117	4.78	118	5.10	125
4.01	5.12	117	5.20	119	5.25	120	5.65	129
4.97	5.48	118	5.56	120	5.62	121	5.80	125
9.35	6.86	115	6.95	116	7.00	117	7.50	126
11.30	7.44	116	7.56	117	7.61	118	7.45	124
13.94	8.06	117	8.16	118	8.24	119	8.55	124
Average		119		121		122		133

The values plotted are the averages of the percentages for different amounts, given in Table VI, taking the value for 0.975 mc. as 100 per cent.

To illustrate the use of these curves we shall calculate the radius on the eighth day for one of the tubes used in the experiment, say 4.01 mc. From Figure 7 the

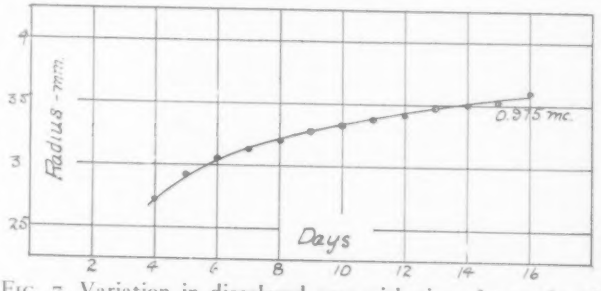


FIG. 7. Variation in discolored area with time, for a tube of 0.975 mc.

radius for 0.975 mc. on the eighth day is 3.18 mm. From Figure 8 the ratio for a tube of 4.01 mc. on the basis of 0.975 as

100 per cent is 1.60. Therefore, the radius for 4.01 mc. on the eighth day is $3.18 \times 1.60 = 5.1$ mm., which agrees very well with the observed value of 5.12 (see Table VIII).

In order to determine whether the same general curves could be duplicated by experiments made at different times the work was repeated. The results for another set of experiments made two or three years previously, are given in Tables VIII and VIIIA. The percentages here

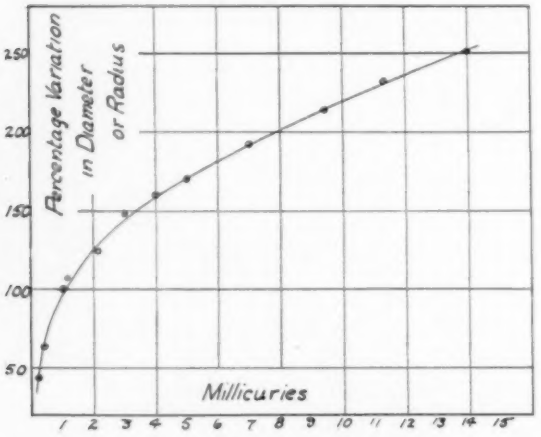


FIG. 8. Average variation in discolored area with initial tube strength.

agree among themselves as in the previous set. To make the proper comparison of the general relations we shall reduce them to the same basis for the 100 per cent values. For this purpose we shall take the value for 1 mc. as 100 per cent, and we shall work out the relative variation from day to day taking the value for 10 days as 100 per cent. The comparison is made in Tables IX and X. It will be seen that while the increase from day to day (Table X)in the area of discoloration is not the same for the two sets of experiments, the 'increase with respect to the strength of the source (Table IX) is practically the same in both cases. The largest discrepancy is less than 3 per cent. From this we may conclude that the relation between the strength of the source in millicuries and the radius of the area of discoloration is nearly the same for experiments made at different times, even when the actual areas and the rate of increase

TABLE VIII

VARIATION OF DISCOLORED AREA WITH INITIAL STRENGTH OF TUBE

Time, Days	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent
	0.2 mc.		0.55 mc.		1.13 mc.		1.93 mc.	
4	0.75	86	1.47	165	2.20	252	2.65	304
6	0.95	92	1.75	170	2.60	252	3.10	302
8	1.10	98	1.92	171	2.83	252	3.35	299
10	1.18	100	2.00	170	2.95	252	3.50	298
12	1.20	100	2.02	169	3.03	252	3.56	297
15	1.24	100	2.05	166	3.10	252	3.62	294
18	1.25	102	2.05	164	3.10	252	3.63	290
Average.		96		168		252		296
	2.83 mc.		3.86 mc.		6.76 mc.		10.15 mc.	
4	3.02	347	3.45	396	4.18	480	4.68	537
6	2.50	340	3.95	383	4.70	457	5.27	510
8	3.80	337	4.23	376	4.95	440	5.65	503
10	3.94	334	4.40	374	5.10	433	5.85	497
12	4.00	333	4.46	372	5.19	432	6.00	500
15	4.06	330	4.53	367	5.25	426	6.10	495
18	4.08	327	4.55	363	5.25	420	6.12	490
Average.		336		375		433		506

TABLE VIIIA

VARIATION OF DISCOLORED AREA WITH TIME OF EXPOSURE

Initial Strength of Tube, Mc.	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent	Radius, Mm.	Per Cent
	4 days		6 days		8 days		10 days	
0.20	0.75	64	0.95	81	1.10	94	1.18	100
0.55	1.47	73	1.75	88	1.92	96	2.00	100
1.13	2.20	75	2.60	88	2.83	96	2.95	100
1.93	2.65	76	3.10	88	3.35	96	3.50	100
2.83	3.02	77	3.50	89	3.80	97	3.80	100
3.86	3.45	78	3.95	90	4.23	96	4.23	100
6.76	4.18	82	4.70	92	4.95	97	4.95	100
10.15	4.68	80	5.27	90	5.65	97	5.65	100
Average.		76		88		96		100
	12 days		15 days		18 days			
0.20	1.20	102	1.24	105	1.25	106		
0.55	2.02	101	2.05	102	2.05	102		
1.13	3.03	102	3.10	105	3.10	105		
1.93	3.56	102	3.62	104	3.63	104		
2.83	4.00	102	4.06	103	4.08	104		
3.86	4.46	102	4.53	103	4.55	103		
6.76	5.19	102	5.25	103	5.25	103		
10.15	6.00	102	6.10	104	6.12	104		
Average.	....	102	....	103	....	104		

TABLE IX

RELATIVE VARIATION OF THE RADIUS OF DISCOLORATION WITH RESPECT TO THE STRENGTH OF THE SOURCE

Millicuries	Per Cent Set VII	Per Cent Set VIIIa	Average
1	100	100	1.00
2	127	130	1.28
3	145	145	1.45
4	159	157	1.58
5	170.6	168	1.69
6	181.4	178	1.80
7	191.6	188	1.90
8	201.6	197	2.00
9	211.0	206	2.08
10	219.6	214	2.17

TABLE X

RELATIVE VARIATION OF THE RADIUS OF DISCOLORATION WITH RESPECT TO THE TIME OF IRRADIATION

Days	Per Cent Set VI	Per Cent Set VIII
4	82	76
5	88	82.6
6	92.7	88
8	97.5	96
10	100	100
12	100.8	102
15		103
18		104

thereof from day to day do not agree very closely. This relation, therefore, is more general. The averages for the two sets are given in Table IX and plotted in Figure 9.

Since the amount of radiation emitted by a tube of radon during a given time interval is proportional to the millicurie-hours, we may examine the relation between the quantity of radiation and the area of discoloration. The experimental data already presented are sufficient for this purpose. We can calculate the millicurie-hours for each tube and each day given in Tables VI to VIIIA and then plot the results. In order not to have too many points on the chart we shall select typical millicurie-values from the tables and give curves for these in Figure 10. No definite conclusions can be drawn from the curves. If the curves for different millicurie values from either set are considered separately, we find that for the same millicurie-hour value the weaker tubes produce a larger

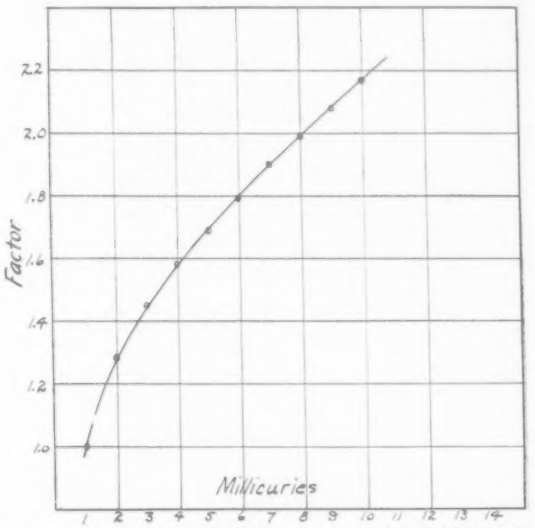


FIG. 9. Variation in discolored area with initial tube strength.

area of discoloration. The difference is much larger for the data of Table VIII than for that of Table VI. The only factor we can find to account for this discrepancy is that the temperature at which the butter was kept was different. The butter for set VIII was kept on ice in an ordinary ice box, while for set VI it was kept in a mechanical refrigerator at a constant temperature of 5°C.

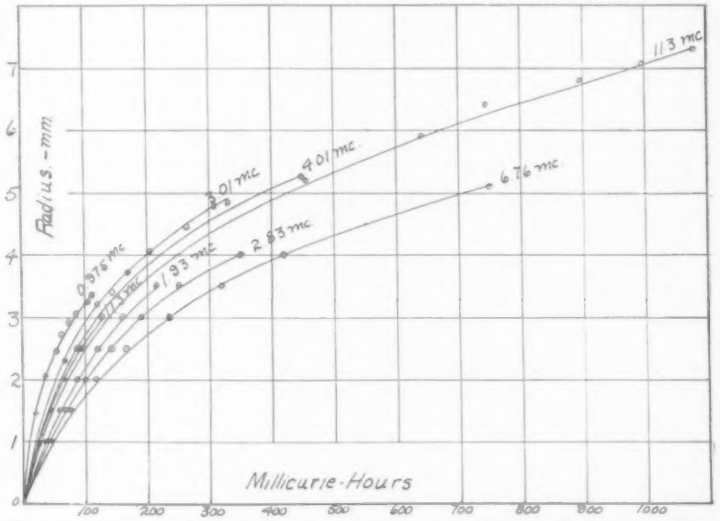


FIG. 10. Variation in discolored area with total millicurie-hours, for different initial tube strengths.

In order to determine the effect of the length of the tube, four tubes were made having nearly the same radon content, but widely different effective lengths. They were all placed in the same Petri dish to insure equality of experimental conditions. The results are shown in Table XI. The width of the area was measured

TABLE XI
EFFECT OF LENGTH OF RADON TUBE ON AFFECTED AREA

Days	Radon tubes of lengths							
	4.3 Mm. (2.5 Mc.)		9.0 Mm. (2.8 Mc.)		15.5 Mm. (2.5 Mc.)		25.0 Mm. (2.7 Mc.)	
	Width	Length	Width	Length	Width	Length	Width	Length
1	6.0	6.3	5.0	11.0	4.0	16.5	3.5	25.8
2	7.5	8.3	7.0	12.6	6.0	18.5	5.5	27.0
3	9.0	9.3	8.5	13.0	7.5	19.1	6.5	27.8
5	11.0	10.3	9.5	15.0	9.0	19.5	8.0	28.0
7	11.0	10.7	10.0	15.4	9.0	20.5	8.0	29.0
9	12.0	11.3	11.0	16.4	9.8	21.1	8.5	29.4
14	13.0	12.7	12.5	16.4	11.0	21.5	9.8	29.4
23	13.0	12.7	12.5	16.4	11.0	21.9	10.0	30.0
30	13.0	12.7	12.5	16.4	11.0	21.9	10.0	30.0

at right angles to the axis of the tube, and the length in the direction of the axis. It will be seen that on the same day the width is smaller for the longer tubes.

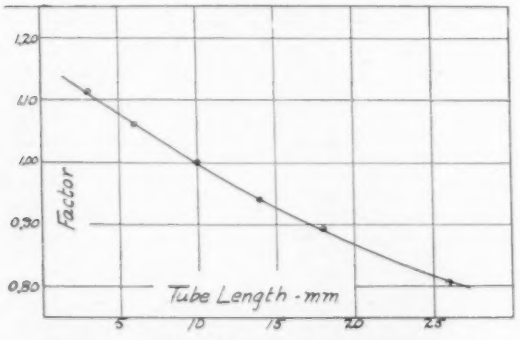


FIG. 11. Correction factor for length of tube.

This is as one would expect, since the tubes contained approximately the same amount of radon.

The above information enables us to determine a correction factor for the length of the tube for values in the neighborhood of 2.5 mc. It is, perhaps, unnecessary to describe the process, but the curve which permits this calculation is given in Figure 11.

The experiments described so far were made with the tubes placed horizontally on the surface of the butter and sunk into it so that the top edge was flush with the surface. The thickness of butter used was equal to the depth of a Petri dish, or about 12 mm. Under these conditions the radiation emitted in the upward direction escaped completely and did not contribute any scattered and secondary radiation. In order to determine what effect this would have on the size of the discolored area, comparative tests were made in which a block of beeswax was placed on top of the Petri dish. Control experiments were made without the wax, with corresponding tubes of about equal strength, using the same butter medium, but in a separate dish. The results, corrected to the same millicurie value for both cases, are shown in Figure 12. The effect of the wax is to

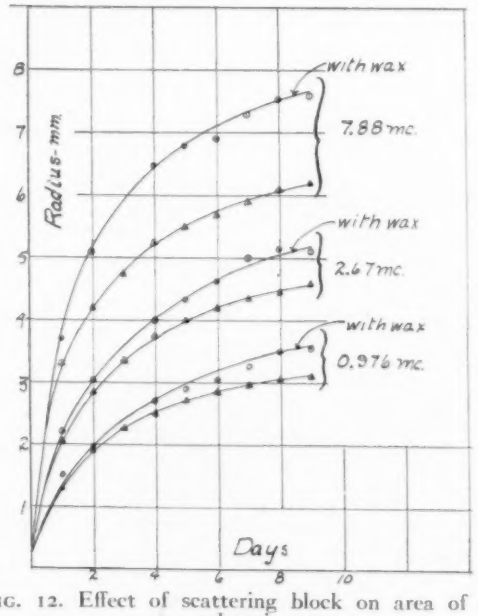


FIG. 12. Effect of scattering block on area of discoloration.

increase considerably the radius of the area of discoloration. The increase appears to be proportional to the radius for the different millicurie values.

The butter discoloration experiments discussed in this paper relate to the definite problem at hand. We may add incidentally that the method lends itself to the investigation of many problems in radium

therapy. Thus the effect of filtration or secondary radiation may be visualized by simple experiments. Great care should be exercised, however, in using any quantitative data thus obtained to predict the biological effects of radium rays.

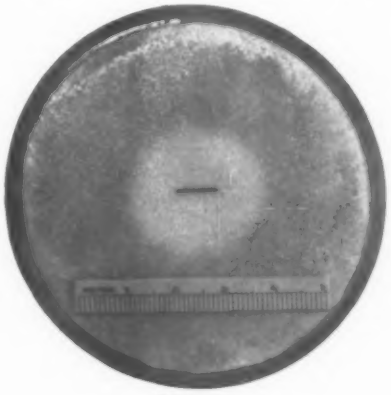


PLATE 1.

PLATE 2.

The appended photographs (Plates 1, 2, 3 and 4) serve to illustrate the experiments. In these, the area of discoloration does not appear as definite as on the surface of the butter.

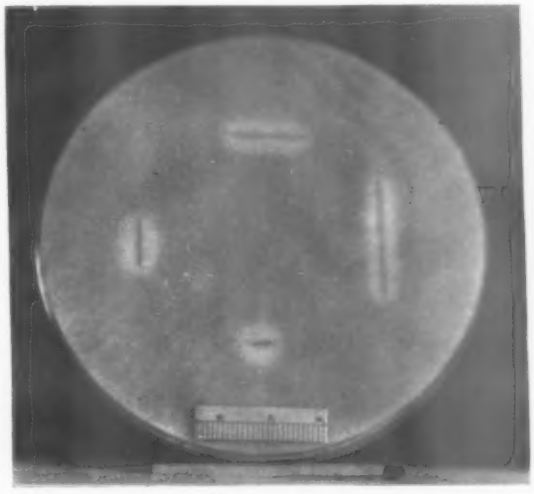


PLATE 3.

PLATE 4.

V. DISCUSSION OF RESULTS

In the first part of the paper we discussed the requirements of the problem. Having obtained the necessary experimental data we shall now develop the relations which exist among the results of the different experiments.

In calculating, by means of the inverse square law and the measured tissue absorption, the radius of action of radiation with respect to a given tissue change, we assumed before that one millicurie left in the tissue for five days would produce the change in question, at a distance of 3 mm. Taking now muscle necrosis as the change, we are able, from the rabbit experiments, to assign a more definite value to this radius. Remembering that in these experiments we found the radius not to increase appreciably after the third or fourth day, we take its maximum value for one millicurie as equal to the one found in the rabbit muscle, that is 2.75 mm. (see Fig. 3). Then following the procedure outlined in Part I, we obtain the results

of Table XII. The values (crosses) are plotted in Figure 13 to show their relation to the results of the rabbit experiments.

TABLE XII

CALCULATED RADII OF NECROSIS RELATIVE TO MAXIMUM RADIUS FOR 1 MC. = 2.75 MM.

Mc.	Mc-hr.	Radius, Mm.
1	133.3	2.75
2	266.6	3.5
3	399.9	3.9
5	666.5	4.6
7	933.1	5.2
10	1333.0	6.0
15	2000.0	6.8
20	2666.0	7.8
25	3340.0	8.3

placed over the surface of the butter on which the tubes rested. It will be recalled that the presence of the wax increased considerably the diameter of the area of discoloration, on account of the additional scattered and secondary radiation. Accordingly, whatever cause is operative in tending to limit the tissue effect must be very powerful.

In order to get a better idea of this cause, we shall make use now of the results of the skin tests. It will be recalled that in these the physical conditions were practically identical with those obtaining in the rabbit experiments. In the former, however, skin erythema was used as the

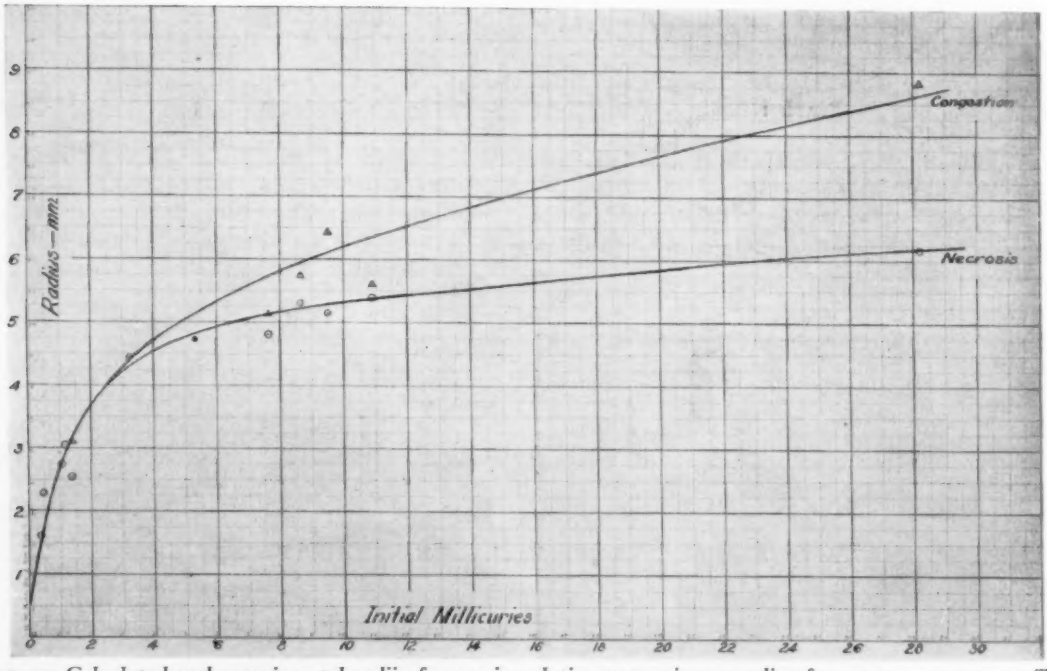


FIG. 13. Calculated and experimental radii of necrosis, relative to maximum radius for 1 mc. = 2.75 mm. (The solid line represents calculated values, the points are experimental.)

It will be seen that they agree closely with the experimental values in the first part of the curve. For higher values than 6 or 7 mc., however, the discrepancy becomes increasingly larger. It is worthy of note that beyond this point the calculated radii are larger than the observed ones in spite of the fact that the scattered and secondary radiation was not included in the calculation. That this is not a negligible factor is evident from the butter experiments, where a block of wax was indicator, while in the latter, tissue necrosis was observed. In comparing the results, we shall consider points at the same distance from the source, so that, the thickness of wax and tissue being identical, the quality of the radiation is essentially the same in the two cases. The comparison is shown in Table XIII. The values in column B were obtained from the curves of Figure 13, and from these the millicurie-hour doses of column C were calculated by the relation: mc-hr. =

TABLE XIII
COMPARISON OF SKIN AND RABBIT EXPERIMENTS

A	B	C	D	E
Radius, Mm.	Initial Millicuries	Mc-hr. (Rabbits)	Mc-hr. Skin	Ratio C/D
1.0	0.21	28.0	1.1	25.2
1.5	0.38	50.7	1.6	31.6
2.0	0.62	82.5	2.2	37.5
2.5	0.87	116.0	3.0	38.7
3.0	1.23	164.0	3.7	44.4
3.5	1.72	229.0	4.5	51.0
4.0	2.48	330	5.5	60.0
4.5	3.70 3.40C	492 453C	6.6	74.5 68.7C
5.0	6.33 4.85C	843 646C	8.0	105 80.7C
5.5	13.50 6.75C	1800 897C	9.7	185 92.4C
6.0	23.0 19.0C	3060 1200C	11.8	206 102C

mc. × 133.3 The values referring to the area of congestion are followed by a C. In column E we have the ratios between the millicurie-hour doses to produce the muscle necrosis (column C), and skin erythema (column D) respectively, for

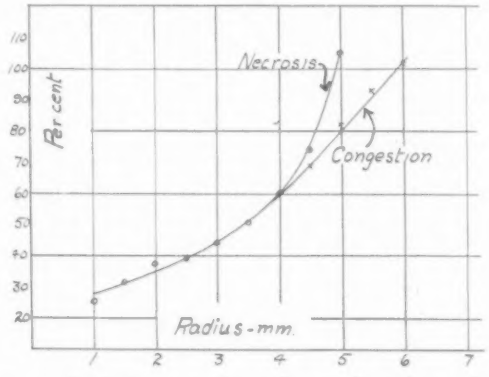


FIG. 14. Ratio between tissue dose and erythema dose.

equal radii (column A). It will be seen that there is no constant relation between the two, but that the ratio increases constantly as the radius increases from 1 to 6 mm. Plotting the ratios against radii we get the curves of Figure 14 from which we see that the millicurie-hour ratio increases very rapidly for values of the radius greater than 4 or 5 mm. Let us inquire now what is the possible significance of this variation.

Referring again to Table XIII we find that at a distance of 1 mm. from the tube 1.1 mc-hr. produces a skin erythema as defined in Part III, while it takes 28* mc-hr. to produce necrosis in a rabbit muscle at the same distance. Accordingly it takes $\frac{28}{1.1} = 25.2$ erythema doses to produce muscle necrosis with the radiation which passes through one millimeter of tissue. Similarly, with the radiation passing through 2 mm. of tissue, it takes 31.6 erythema doses, etc. It will be seen then, that the number of erythema doses required to produce muscle necrosis increases rapidly as the thickness of intervening tissue increases.

TABLE XIV
RELATIVE AMOUNTS OF BETA AND GAMMA RADIATION REACHING VARIOUS TISSUE DEPTHS

A	B	C
Tissue, Mm.	Beta, Per Cent	Gamma, Per Cent
0	96.5	3.50
1	88.0	12.0
2	78.5	21.5
3	67.6	32.4
4	55.5	44.5
5	43.0	57.0
6	31.7	68.3
7	22.7	77.3
8	17.2	82.8
10	7.4	92.6

In attempting to account for this difference we shall consider first the variation in the quality of the radiation with the tissue thickness. In Table XIV we give the percentages of beta and gamma radiations in the emergent beam for different thicknesses of tissue.[5] It will be seen that from zero to 4 mm. the beta is more than the gamma radiation, and that some beta rays pass through even 10 mm. of tissue. The composition of the radiation, therefore, is quite different at different distances from the tube. The transition from a predominance of beta to a predominance of gamma radiation occurs between 4 and 5 mm. and this is the point at which the ratio curve of Figure 14 becomes very steep. Accordingly, one conclusion we may draw is that gamma radiation and hard beta rays are less effective than soft beta rays in producing

*This really is not the minimum necessary dose—see later.

muscle necrosis *than they are in producing skin erythema.*

The above statement is not to be confused with the well-known fact that beta rays from radium are biologically more effective than gamma rays, by virtue of their greater intensity and their larger absorption. We know, for instance, that a skin erythema is produced on the average patient[1] by 7.5 mc-hr. using a tube of radon without filter, at a distance of 2 cm. On the other hand, if a filter of 2 mm. of brass is used, in which case no beta rays pass through it, the millicurie-hour erythema dose for the same conditions is 830, or 111 times larger. This increase is due to the fact that a large part of the total radiation is absorbed by the brass, and that the gamma rays which pass through are not easily absorbed by tissue. The additional information we may derive from the rabbit experiments is that, if instead of taking *skin erythema* as the indicator, we take *muscle necrosis*, the difference between the beta and gamma ray millicurie-hour doses under the same conditions is much greater. It should be noted also that the beta rays which are able to pass through 4 or 5 mm. of tissue are not very effective in producing necrosis.

Considering the rapidity with which the ratio values increase beyond a 5 mm. radius (Fig. 14), we may conclude that extremely large doses are required to produce muscle necrosis at greater distances. But probably we are not justified in generalizing to the extent of saying that extremely large doses are necessary to produce muscle necrosis with gamma rays under other conditions. We do not see, however, what other factors, in addition to the quality of the radiation, might influence the ratio. Those we have thought of, apparently, would exert the same influence independently of the distance. To make this point clear, we shall consider some of them:

1. *Rate of Administration of Radiation.* If we measure the radiation by its ability to produce an erythema, the millicurie hour doses are inversely proportional to the "intensity" of radiation at corresponding distances from the source. The relative intensities calculated on this basis are given in column C of Table xv. Multiplying the value for each distance by the millicurie value required to produce necrosis at that distance, we get the relative rate of administration of radiation at that distance. The results are shown in columns F and G of Table xv. It will be seen that for the larger radii the rate is higher than for the shorter distances, and therefore the difficulty of producing necrosis at the longer distances cannot be attributed to this factor.

TABLE XV
IRRADIATION RATES FOR NECROSIS AND CONGESTION

A	B	C	D	E	F	G
Radius, Mm.	Skin Dose, Mc-hr.	Intensity, Per Cent	Millicuries for Irradiation Rate			
			Necrosis	Congestion	Necrosis	Congestion
1	1.1	100	0.21	.....	21.0	
1.5	1.6	68.8	0.38	.....	26.2	
2.0	2.2	50.0	0.62	.....	31.0	
2.5	3.0	36.6	0.87	.....	31.8	
3.0	3.7	29.7	1.23	.....	36.5	
3.5	4.5	24.5	1.72	.....	42.2	
4.0	5.5	20.0	2.48	.....	49.6	
4.5	6.6	16.7	3.70	3.40	61.8	56.8
5.0	8.0	13.7	6.33	4.85	86.8	66.5
5.5	9.7	11.3	13.50	6.75	153	76.3
6.0	13.0	8.55	23.0	9.0	197	77.0
6.5	16.0	6.88	.....	11.9	.....	82.0
7.0	20.0	5.50	.....	15.2	.....	83.5
7.5	25.0	4.40	.....	18.8	.....	82.8
10	60	1.83	.....	45.5*	.....	83*
15	250	0.44	.....	190.0*	.....	83*
20	800	0.14	.....	590.0*	.....	83*

* Estimated.

2. *Repair Process.* In dealing with living tissue, we must consider the process which tends to repair the damage caused by the radiation. Since, however, the time interval in the rabbit experiments was about the same for the different millicurie values, it does not appear that this factor would have an influence in limiting the necrosis *relatively more* for the stronger tubes than for the weaker ones. The blood supply would be more abundant around the larger volumes of necrosis, but the damaged tissue would be proportionately more. It is known that the biological action of radiation does not manifest itself immediately, but that a certain time elapses between the time of application and the appearance of a change. If this latent period is sufficiently longer for gamma radiation than it is for beta rays, we may

account for the relatively small amount of necrosis produced by the stronger tubes on ths basis that the tissue was examined before the full effect had developed. On the other hand, if the muscles had been removed after a much longer time, the difference in the extent to which the repair process had progressed would have complicated the results. In any case, it is doubtful whether the final area of necrosis would have been essentially larger.

In view of these considerations we may conclude that the available information points to a differential action of radium radiation as regards human skin erythema and rabbit muscle necrosis. Predominantly beta radiation is more effective in producing muscle necrosis than it is in producing skin erythema, while predominantly gamma radiation is relatively less effective in producing muscle necrosis than it is in producing skin erythema.

We shall return now to the discussion of the erythema doses required to produce necrosis or congestion at different distances from the radon tube. The millicurie-hour doses given in column C, Table XIII were calculated on the basis of complete disintegration of the radon in the tubes used. Since it was found that the area of necrosis did not increase appreciably after a few days, these figures give the upper limit of the dose. The lower limit, or the dose which is just sufficient to cause the observed amount of necrosis, is therefore much smaller. It depends naturally on the duration of irradiation necessary to produce the maximum amount of necrosis for each millicurie value. If we take four days, as our experiments seem to indicate, we get the results of columns F and G of Table XVI. These show that it takes 13.1 erythema doses of the radiation passing through one millimeter of tissue to produce muscle necrosis, while 122 erythema doses are required if the radiation passes through 6 mm. of tissue. To produce marked tissue congestion at this point, 50.8 erythema doses are necessary. If we take one day instead of four, for the time interval, we get the erythema dose values shown in columns H and I of the same table.

TABLE XVI

NECROSIS AND CONGESTION DOSES IN TERMS OF ERYTHEMA DOSES

A	B	C	D	E	F	G	H	I
	Millicurie-hours for				Erythema Doses for			
	4 Days		1 Day		4 Days		1 Day	
Radius mm.	Necrosis	Congestion	Necrosis	Congestion	Necrosis	Congestion	Necrosis	Congestion
1	14.4	.....	4.6	.....	13.1	.....	4.2	
2	42.4	.....	13.6	.....	19.3	.....	6.2	
3	84.2	.....	27.0	.....	22.7	.....	7.3	
4	170	.....	54.5	.....	31.0	.....	9.8	
5	433	326	139	106	54	40.1	17.4	13.2
6	1570	618	507	192	122	50.8	41.5	15.8
7	.....	1040	.....	330	.....	52.0	.....	16.5

In either case, however, the doses are perhaps higher than one would expect. In this connection it is well to recall that many biological inequalities exist between the skin tests and the rabbit experiments. Furthermore, the rate of administration of radiation was distinctly different in the two types of experiment. The duration of the irradiation in the skin tests varied from a few minutes to four hours, being longer in general for the larger thicknesses of wax. The strength of the radon source, therefore, was practically constant during this time. In the rabbit experiments, on the other hand, the tissues were irradiated continuously for a number of days, —four to eight. In this time a large variation in the strength of the source occurred, and the irradiation became gradually less intense.

Experiments similar to ours with rabbit muscles have been reported by Lacassagne.[4] For purposes of comparison we have plotted his data and ours in Figure 15. As far as we can learn from the paper, each point given represents a single determination and not the average of many tests as in our case. Then we do not know whether the zone of congestion was included in the measured radii. Remembering the large variations which we found from one specimen to another, the differences between Lacassagne's curve and ours for

the outer diameter of the affected area, are not significant. On account of the large number of animals we used, our results probably represent better the average conditions, and are less uncertain. In regard to the relation between the radiation dose and the area of necrosis produced, our results substantiate Lacassagne's findings. That is, the initial strength of the tube determines the extent of the resultant effect. However, we found that the area of the necrosis continued to increase after the first day.

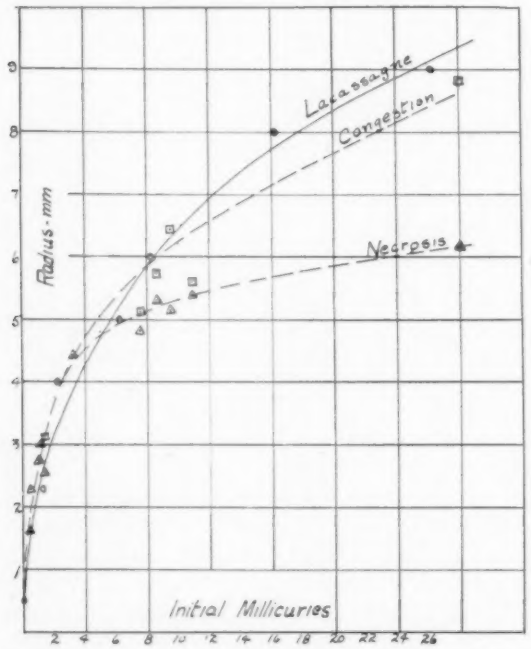


FIG. 15. Variation in affected area with initial tube strength. Comparison of data obtained by Lacassagne and the authors.

We may discuss at this point the fact that a zone of congestion is present in the specimens for tubes of more than 5 mc., but in general, is not discernible when weaker tubes are used. Whatever the biological reason for this may be, there is one physical factor which must have some influence on it. Due to the inverse square law, the drop in the radiation intensity from millimeter to millimeter becomes rapidly less as we move away from the source. In addition, the filtering effect of the intervening tissue makes the radiation more penetrating, and hence the amount absorbed by successive millimeters of tissue becomes less and less. Also, the effect of the scattered and secondary radiation tends to increase the intensity at the greater distances. Accordingly, the differences between the amount of radiation reaching successive layers of tissue become relatively small beyond the 5 mm. range, which is approximately the radius of the necrotic area produced by a tube of 5 mc. Since the distribution of radiation shades off gently from this point on, it is reasonable to expect a corresponding gradation in the histological effects. The zone of congestion, therefore, represents a region where the radiation is not quite sufficient to produce necrosis, but is capable of causing a little less severe, but still marked, tissue reaction. For small radii, the drop in the radiation intensity is very abrupt, and the zone of congestion is either absent or too narrow to be visible in the gross specimen.

We shall proceed now to the correlation of the results of the butter experiments with those of the rabbit experiments. We have seen that the radius of the area of discoloration depends in some degree on the specimen of butter used, and probably on the temperature at which it is kept. On the other hand, the relative variation of the radius with the millicurie value of the source is practically the same under different conditions. Accordingly, we shall use this generalized relation for purposes of comparison.

TABLE XVII

CALCULATED AND EXPERIMENTAL RADII NECROSIS

A	B	C	D	E
Mc.	Factor (Butter Exp.)	Calculated Radius of Necrosis	Observed Radius of	
			Necrosis	Congestion
1	1.00	2.75	2.75	
2	1.27	3.5	3.70	
3	1.45	4.0	4.25	
4	1.59	4.37	4.57	4.73
5	1.71	4.7	4.80	5.05
6	1.81	5.0	4.95	5.3
7	1.92	5.3	5.07	5.56
8	2.02	5.55	5.16	5.80
9	2.10	5.8	5.23	6.0
10	2.20	6.0	5.30	6.18

In Table XVII the values of column B are taken from the general butter dis-

coloration curve of Figure 8. We shall use these to predict the radii of necrosis in rabbit muscle for different millicurie values, assuming that we know the radius for a given radon tube. We shall take for this 2.75 mm., the average value found experimentally for 1 mc. tubes. Multiplying this by the factors of column B we get the radii of necrosis of column C for different millicurie values. The radii experimentally determined are given in columns D and E for comparison. We see that the agreement is quite close, especially if we consider for the stronger tubes an average of the inner and outer radii of the zone of congestion.

Inasmuch as the radius of action of the tubes in rabbit muscle has been determined experimentally, there is, of course, no advantage in calculating it from the butter discoloration data. What we wish to bring out, however, is that, under suitable conditions, the results of butter discoloration experiments can be used to predict tissue effects with reasonable precision. Needless to say, care must be exercised not to make too broad generalizations, because we can never expect butter to respond to the radiation in the same way that living tissue does.

VI. PRACTICAL APPLICATIONS

The experimental work we have described in this paper enables us to predict with reasonable precision the area of necrosis or congestion which would result in rabbit muscle in which a radon tube of 0.5 to 10 mc. had been embedded. We also know the dose in terms of human skin erythema units necessary to produce necrosis or congestion at different distances from the buried tube. The experiments with butter, furthermore, confirm to a certain degree the results of the rabbit experiments, and supply additional data as to the influence of the size of the radioactive source, etc. We have, therefore, sufficient reliable information to predict the probable effect in rabbit muscle produced by a combination of tubes embedded therein. This, however, is of no practical value since no one is interested in treating rabbits with radium. We shall therefore discuss now how the results of our experiments may be utilized in the treatment of cancer with buried radon. In some institutions this method has been used for many years, and a great deal of clinical information has been gathered. It is known also from the study of tumors treated in this way and then removed surgically, that tissue changes are produced corresponding at least *qualitatively* with those observed in rabbit muscle. No quantitative data are available, and the difficulties in obtaining them are perhaps insurmountable.

From general considerations we may expect the area of necrosis and zone of other tissue changes to vary from one type of tissue to another with the radiosensitivity of the tissue, other conditions remaining the same. It is not unreasonable to assume, however, that *for any one type of tissue* some relation, similar to the one found for rabbit muscle, would exist between the strength of the source and the radius of the area affected. If the density of the tissue is approximately the same as that of rabbit muscle, the distribution of radiation will be practically the same as in the rabbit experiments. Then if the radiosensitivity of the tissue is not far removed from that of rabbit muscle, we can be reasonably sure that the relation between strength of tube and radius of the affected area, which we found experimentally, will apply to the new tissue also. The density of most animal tissues differs very little. The fact that the radium therapist resorts to the method of buried radon indicates in a general way that he wishes to administer heavy doses to the particular tumor he is treating, because in his experience he has found it to be resistant to radiation. Therefore we may reasonably assume that the experimental relation obtained for rabbit muscle is applicable to those tumors which ordinarily would be treated with buried radon.

For dosage purposes we want to know how many tubes are required to treat effectively a certain tumor; how they should be placed within the tumor to obtain the most uniform distribution of radiation; and what should be the millicurie strength of each tube. If it were a question of simply destroying the tumor

by radiation, the problem would be very simple, because we could make sure, on the basis of the rabbit experiments, that the dose throughout the mass would be sufficient to cause complete necrosis. Unfortunately, however, the radiation affects also the normal tissues around the tumor, and it is important not to injure them too severely. Accordingly a certain balance must be struck between the effects on the tumor and the normal tissues. What this proper balance is for any particular case can be determined only by clinical observations.

Those who have had a great deal of experience in the treatment of cancer with buried radon, have arrived empirically at certain doses for different tumors, which they have found to be effective. Let us suppose then that we know the number of tubes and the total amount of radon required to treat successfully a given tumor. The data presented in this paper enable us to calculate the resultant distribution of effective radiation throughout the tumor mass, for any assumed spacing of the tubes. By repeated trials we can determine the spacing which will give the most uniform distribution of the radiation. Since in practice a relatively small number of discrete sources is used, some points in the tumor receive less radiation than others and we can estimate what the dose is at these points. Naturally if the tumor disappears, it means that the dose at these points of minimum intensity is sufficient to cause the desired result. In this way it will be seen that we can arrive at the dose which the tumor must receive in order to be affected favorably. In reality this is not the minimum dose necessary to bring about the disappearance of the tumor because in practice the tubes can never be inserted according to the ideal spacing. It is, however, the minimum dose which should be administered to every point of the tumor in order to insure a sufficient margin of safety for an uneven distribution of the tubes. Having obtained thus the required minimum dose, we can determine the number of tubes and the total amount necessary to treat similar tumors of different sizes. It will be seen that the accuracy of such determinations will depend to a large measure on the accuracy of the minimum dose adopted. On this account we decided to determine this quantity from clinical dosage data for tumors of several different sizes and shapes.

Using dental modeling compound we made ten hypothetical "tumors" ranging in linear dimensions from 1.5 to 5 cm. and having different shapes (Plate 5). We then asked Dr. Douglas Quick what doses he would use for the treatment of these tumors. The data thus obtained are given in columns C and D of Table XVIII. In this connection several additional factors should be mentioned. The above doses are for epidermoid carcinoma occurring around

PLATE 5.

TABLE XVIII

EMPIRICAL MILLICURIE DOSES FOR HYPOTHETICAL TUMORS

A	B	C	D
Tumor No.	Dimensions Mm.	Number Tubes	Total Mc.
1	Sphere—radius 7.35	2	2
2	Sphere—radius 8.5	3	3
3	Oval, 21.5 × 18 × 11	5	5
4	Oval, 30 × 21 × 11	7	7
5	Sphere—radius 10.7	6	6
6	Oval, 50 × 21 × 12	15	15
7	Oval, 40 × 30 × 15	10	10
8	Sphere—radius 15	9	9
9	Sphere—radius 20	18	18
10	Sphere—radius 25	25	25

the mouth. The smaller tumors are assumed to be primary lesions and the larger ones metastatic nodes. In practice the doses would be affected somewhat by (1) the character of the tumor; (2) the character of the tissue around it; (3) the blood supply; (4) whether the capsule is perforated; (5) whether infection is present; (6) the space relation to vital structures, etc. In general, also radiation (either radium or roentgen rays) would be administered externally some time in advance of the radon treatment. The above doses, however, refer to the average conditions met with in practice. Dr. Quick supplied, also, additional information as to the distribution of the tubes within each tumor. His general plan is to make sure that the periphery of the tumor is sufficiently irradiated. Accordingly in the large tumors the tubes are distributed evenly over the outer shell of the mass. This is the ideal arrangement aimed at, but of course in practice it is very difficult to obtain.

TABLE XIX

RADIATION INTENSITIES AT DIFFERENT DISTANCES FROM THE RADON TUBE, BASED ON NECROSIS AND CONGESTION EFFECTS

Radius, Mm.	Millicuries		Intensity	
	For Nec.	For Cong.	For Nec.	For Cong.
1.0	0.21	....	100	
2.0	0.62	....	33.8	
2.5	0.87	....	24.1	
3.0	1.23	....	17.1	
3.5	1.72	....	12.2	
4.0	2.48	....	8.44	
4.5	3.70	3.40	5.66	6.18
5.0	6.33	4.85	3.32	4.32
5.5	13.50	6.75	1.55	3.11
6.0	23.0	9.0	0.95	2.33
6.5	.....	11.9	.....	1.76
7.0	.....	15.2	.....	1.38
7.5	.....	18.8	.....	1.12

We shall now combine the experimental and the clinical data to see what useful practical generalizations may be derived. Referring to Table XII, Part V, we find that it takes a tube of 5 mc. to produce necrosis in rabbit muscle at a distance of 4.6 mm. Hence a tube of 1 mc. would deliver at the same distance one-fifth of the dose required to produce necrosis. We see, therefore, that the intensity of the radiation at any given distance from the tube, based on its ability to produce necrosis, is inversely proportional to the millicurie value of the tube which would produce necrosis at that point. The same reasoning applies to the case where congestion is taken as the tissue effect instead of necrosis. Making the calculation outlined here, we get the results of Table XIX relative to the intensity at a distance of 1 mm. as 100 per cent. With this information we can calculate the resultant dose at a given point due to a number of tubes in its vicinity. We find, however, that the effect of tubes at greater distances than 7.5 mm. cannot be neglected, and therefore it is necessary to extend the table.

To do this we proceed as follows: In Table XX we have the millicurie-hours required to produce an erythema at different distances from the buried radon tube. The reciprocals of these values give the intensity of radiation at the different points as measured by its ability to produce a skin erythema. The values relative to the intensity at 1 mm. distance as 100 cent are tabulated in the last column. For purposes of comparison we may take these as being the intensities corresponding to a source of 1 mc. Then for any other strength of the source, the intensities will be proportional to the radon content in millicuries. Now from the rabbit experiments we have the millicurie values required to produce necrosis or congestion at different distances from the source. Multiplying each by the corresponding value for the intensity of the radiation from a 1 mc. tube as just determined from the skin erythema tests, we find the intensities at the different distances at which necrosis or congestion is obtained, based on the effectiveness of the radiation in producing skin erythema. The values thus calculated are given in Table XXI. A numerical example will bring out better the reasoning involved: To produce necrosis at a distance of 1 mm. a tube of 0.21 mc. of radon is required (see Col. B, Table XXI). At this distance (1 mm.) we have assumed the intensity of radiation as measured by its effectiveness in producing skin erythema, to be 100 arbitrary units for a source of 1 mc. (see

Col. D). Then for a tube of 0.21 mc. the intensity at the same point would be 100 × 0.21 = 21 of the same arbitrary units. Similarly for a distance of 2 mm. the intensity is 50 units when the strength of the source is 1 mc. and therefore it will be 50 × 0.62 = 31 units for a tube of 0.62 mc.

TABLE XX

RADIATION INTENSITY AT DIFFERENT DISTANCES FROM THE RADON TUBE, BASED ON SKIN ERYTHEMA EFFECT

Mm.	Mc-hr.	Intensity Per Cent
1	1.1	100
2	2.2	50
2.5	3.0	36.6
3.0	3.7	29.7
3.5	4.5	24.5
4.0	5.5	20.0
4.5	6.6	16.7
5.0	8.0	13.7
5.5	9.7	11.3
6.0	13.0	8.55
6.5	16.0	6.88
7.0	20.0	5.50
7.5	25.0	4.40
8.0	30.0	3.66
9.0	42.5	2.59
10.0	60.0	1.83
12.0	114	0.963
14.0	195	0.564
17.0	405	0.272
20.0	830	0.133

TABLE XXI

RADIATION INTENSITIES FOR THE MILLICURIE VALUES REQUIRED TO PRODUCE NECROSIS OR CONGESTION, BASED ON THE EFFECTIVENESS OF THE RADIATION IN PRODUCING SKIN ERYTHEMA

A	B	C	D	E	F
Mm.	Millicuries		Per cent Intensity (Erythema)	Intensity (Erythema) for	
	Necrosis	Congestion		Necrosis	Congestion
1	0.21	....	100	21	
2	0.62	....	50	31	
2.5	0.87	....	36.6	32	
3.0	1.23	....	29.7	36.4	
3.5	1.72	....	24.5	42	
4.0	2.48	....	20.0	49.6	
4.5	3.70	3.40	16.7	62	56.8
5.0	6.33	4.85	13.7	87	66.5
5.5	13.50	6.75	11.3	152	76.3
6.0	23.0	9.0	8.55	196	77.0
6.5	.....	11.9	6.88	.....	82.0
7.0	....	15.2	5.50	....	83.5
7.5	....	18.8	4.40	.....	82.8

It will be seen that the intensities for the zone of congestion (Col. F, Table XXI) tend to become constant at the longer distances. This is due to the fact that the quality of the radiation does not change so rapidly after filtration by a few millimeters of tissue. On this account the possible differential effect mentioned in Part V is not so prominent. In other words, the ratio between the dose required to produce congestion, and the dose which would produce an erythema at the same distance tends to become constant. Assuming that the value in Col. F of Table XXI remains 83 for distances from 8 to 20 mm., we can reverse the calculation and thus determine the millicurie values (as in Col. C) for this additional range of distances. From these we can then determine the desired intensities up to a distance of 20 mm. for the effectiveness of the radiation in producing congestion. Table XXII is

TABLE XXII

EXTENSION OF TABLE XIX

Radius, Mm.	Mc. for Congestion	Intensity for Cong.
8.0	22.7	0.925
9.0	32.1	0.655
10.0	45.4	0.463
12.0	86.3	0.244
14.0	147	0.143
17.0	305	0.069
20.0	622	0.034

TABLE XXIII

RADIATION INTENSITIES AT DIFFERENT DISTANCES FROM A 1 MC. TUBE IN TERMS OF THE VALUE WHICH PRODUCES NECROSIS OR CONGESTION AS 100 PER CENT

Distance	Intensity
1	476
2	161
2.5	115
2.75	100
3.0	81.5
3.5	58.0
4.0	40.1
4.5	29.5
5.0	20.6
5.5	14.8
6.0	11.1
6.5	8.40
7.0	6.58
7.5	5.34
8.0	4.42
9.0	3.12
10.0	2.21
12.0	1.12
14.0	0.68
17.0	0.33
20.0	0.16

the continuation of Table XIX, worked out on this basis. Since a 1 mc. tube produces necrosis, (or congestion, the two effects being indistinguishable in this region) at a distance of 2.75 mm., we shall take the value for this point as 100 per cent. Then the values for the intensities at greater distances will represent the dose delivered by a tube of 1 mc. in percentages of the dose required to produce tissue congestion at that distance. The values

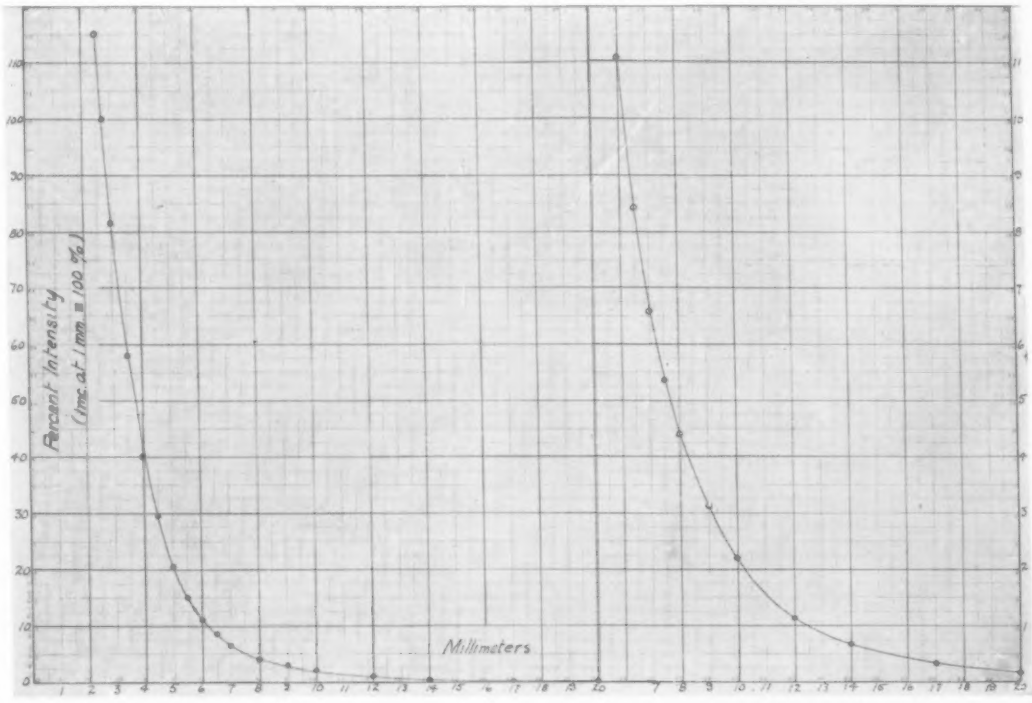


FIG. 16. Radiation intensities necessary to produce congestion at different distances from the source.

are given in Table XXIII and are plotted in Figure 16. If, therefore, we consider the combined effect at a certain point, due to radiation from several tubes by means of this curve, we get the dose at the point in question in terms of the dose necessary to produce congestion.

It may be well to give now the reasons for basing the calculation of the intensity of radiation on the congestion, instead of the necrosis effect for the stronger tubes. The curve of Figure 16 is to be used for the determination of the distribution of effective radiation in a tumor in which several or many tubes have been embedded. Or vice versa it is to be used to determine the number and distribution of 1 mc. tubes necessary to treat a given tumor. In practice the radon tubes are not placed, generally, close enough to one another for the necrotic areas to overlap. Accordingly the radiation effect involved in the treatment of a tumor is not necrosis but something else. In our opinion, therefore, congestion, being a less severe effect than necrosis, represents more closely the desired effect on the tumor tissue.

We are now in a position to determine the minimum dose previously mentioned, for each of the hypothetical tumors of Table XVIII. To do this we shall take the number of 1 mc. tubes prescribed by Dr. Quick, and we shall arrange them in such a way as to give the most desirable distribution of the radiation. By this we mean the arrangement which gives the most uniform distribution of the radiation, compatible with the conditions set forth by Dr. Quick. These are, (1) the periphery of the tumor should receive at least as much radiation as any other part; (2) in small tumors the whole mass should be irradiated as uniformly as possible; (3)

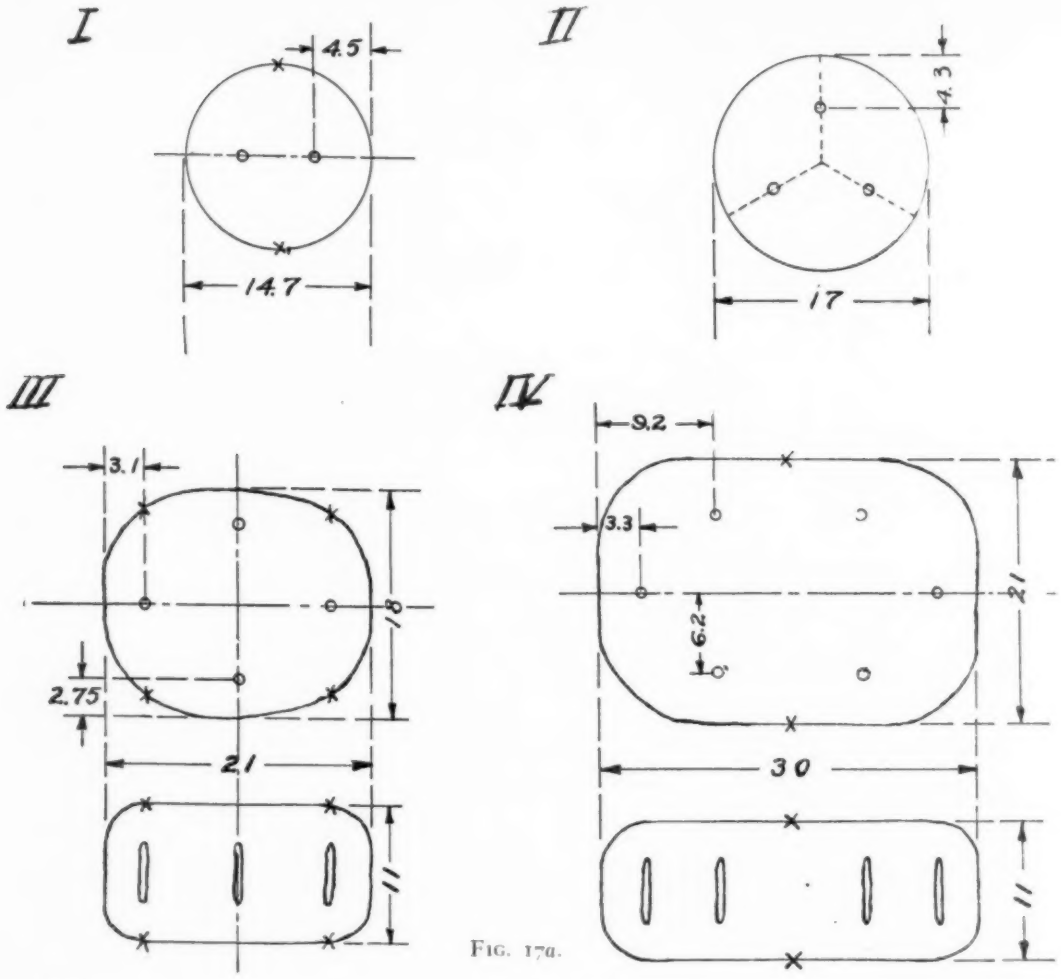


FIG. 17a.

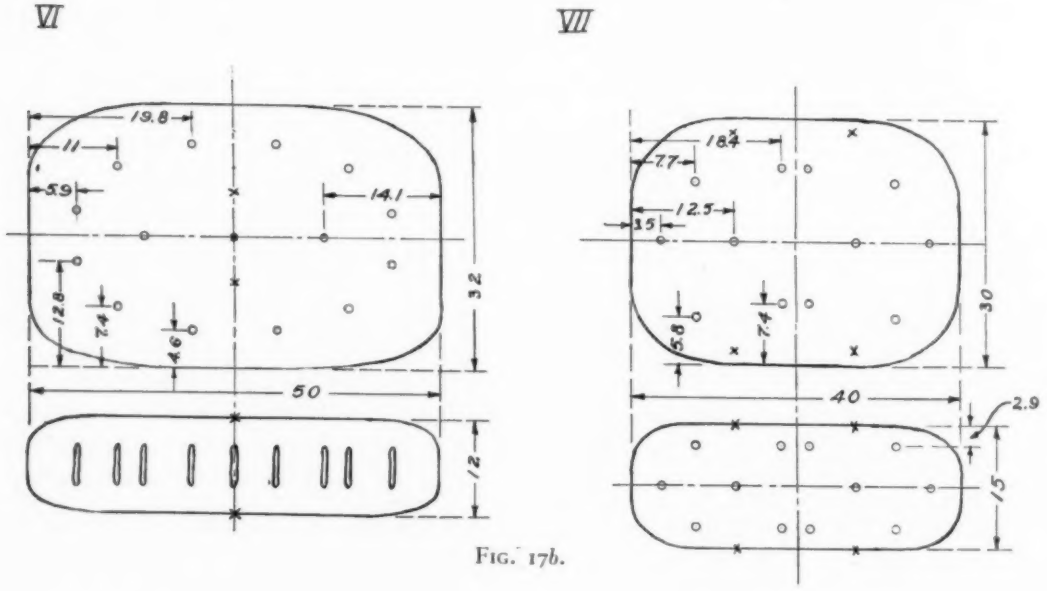


FIG. 17b.

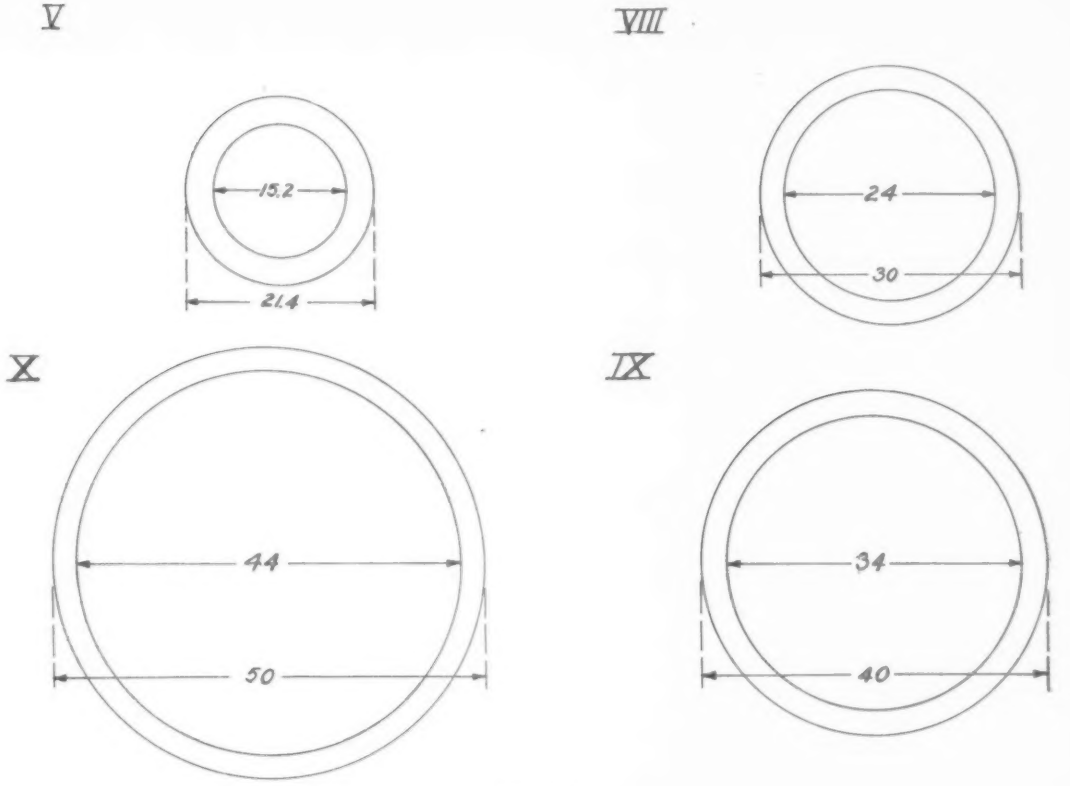


FIG. 17c.

FIG. 17. Model tumors, showing correct distribution of radon tubes. The dimensions of each model are given and the location of the tubes indicated. The points receiving minimum radiation with these distributions of tubes are indicated by crosses. I. Sphere, 7.35 mm. radius; 2 tubes, 1 mc. each. II. Sphere, 8.5 mm. radius; 3 tubes, 1 mc. each. The actual minimum here would be at the end of the axis perpendicular to the section shown. III. Oval, 21.5 × 18 × 11 mm. 4 tubes, 1 mc. each. The minima are on the rounded edges of the model. IV. Oval, 30 × 21 × 11 mm. 6 tubes, 1 mc. each. The minima are on the rounded edges of the model. V. Sphere, 10.7 mm. radius; 6 tubes, 1 mc. each. The tubes are distributed uniformly over the surface of the inner sphere. The minima are on the surface, at the centers of triangles formed by the tubes. VI. Oval 50 × 32 × 12 mm. 15 tubes, 1 mc. each. The minima are on the flat surfaces, as indicated by the crosses. VII. Oval 40 × 30 × 15 mm. 10 tubes, 1 mc. each. The tubes are distributed on three planes, as indicated, corresponding tubes having the same number in the two views. The minima are on the flat surfaces, as indicated. VIII. Spheres of radii 15 mm., 20 mm., and 25 mm. respectively. IX. Tubes, 9, 18, and 25 respectively, all of 1 mc. each. X. In each case the tubes are to be distributed uniformly over the surface of a sphere inside the tumor, concentric with it and having a radius 3 mm. less. The area of this inner sphere is supposed to be divided into as many squares as there are tubes, and each tube to lie at the center of a square. The minima are then at the corners of the squares.

in large globular tumors the central core need not be considered; (4) the area of necrosis around each tube must not extend too far into the surrounding normal tissue.

In accordance with the above conditions, we decided that a tube could not be put closer than 3 mm. to the periphery for small tumors, and should be at this distance from the surface for the larger ones. The reason for taking 3 mm. as this distance is as follows: The average radius of the necrotic area produced in rabbit muscle by a tube 11 mm. long, containing 1 mc. of radon was 2.75 mm. The tubes used in therapy are usually about 4 mm. long, and according to the butter experiments, (q.v.) the radius of necrosis for this length should be larger,—that is, a little more than 3 mm. Considering also variations in this radius which are apt to occur, we decided that it would be safe to use 3 mm.

Assuming at first a reasonable spacing for the tubes in each "tumor" we determined the resultant intensity of radiation at different points on the surface and within the tumor mass, using the curve

of Figure 16. The actual procedure was as follows: Taking a certain point in the tumor, we determined the distance between each tube and the point in question. Then the intensity corresponding to each distance was read from the curve of Figure 16. The sum of the intensities for all the tubes would then be the resultant intensity at the given point. On account of the limited number of tubes used, of course the intensity thus calculated varied a great deal from point to point. The tubes were then rearranged to improve the distribution of radiation. Each time that this was done, especial attention was paid to the point at which the intensity was lowest. A convenient criterion to use for the most desirable arrangement, was suggested by the variation of this minimum intensity as the position of the tubes was shifted. The optimum arrangement is the one for which the minimum intensity is closest to the average for all important points. Proceeding on this basis the most desirable arrangement of the required number of 1 mc. tubes was worked out for each tumor. The spacing finally arrived at is shown in the accompanying diagrams (Fig. 17). The points which receive the smallest dose are indicated by crosses (x).

The minimum intensities for the most desirable arrangement of the tubes, are given in column G of Table XXIV. We have tabulated also the dimensions of the tumor (column A), the volume, determined by the amount of water it displaced in a graduate (column B), the surface area, estimated as closely as possible (column C), the number of 1 mc. tubes prescribed by Dr. Quick (column D), the millicuries per cubic centimeter (column E), and the millicuries per square centimeter (column F). From the values in column E we see that with one exception the millicuries per cubic centimeter for each tumor from 1 to 6 agree closely. The millicuries per square centimeter (column F) agree closely for all the tumors. This is really remarkable considering that Dr. Quick estimated the doses for each tumor *without taking any measurements.*

Examining the minimum intensities of column G we find a fairly good agreement among the first six, and a better one among the last four. The values for tumors numbers 3 and 4 are considerably higher than for the others. In view of this we changed the number of tubes from 5 to 4 and from 7 to 6, respectively, and recalculated the intensities for the new arrangements. They are 10.5 and 10.3 respectively (Table XXV) and agree closely with the others for the first six tumors. On this basis, then, Dr. Quick recommended one

TABLE XXIV

MINIMUM INTENSITIES FOR HYPOTHETICAL TUMORS

	A	B	C	D	E	F	G
No.	Tumor	Volume, C.c.	Area, Cm.^{2}	No. Tubes of 1 Mc.	Mc. per C.c.	Mc. per Cm.^{2}	Minimum Intensity
1	Sphere, 7.35 mm. radius	1.7	6.8	2	1.3	0.30	9
2	Sphere 8.5 mm. radius	2.6	9.1	3	1.15	0.34	9.4
3	Oval, 18 × 21.5 × 11 mm.	2.9	10.9	5	1.72	0.46	13.9
4	Oval, 21 × 30 × 11 mm.	5.8	19.6	7	1.21	0.36	14.8
5	Sphere, 107 mm. radius	5.1	14.3	6	1.20	0.42	8.0
6	Oval, 50 × 32 × 12 mm.	13	42.4	15	1.16	0.35	9.3
7	Oval, 40 × 30 × 15 mm.	15	37	10	0.67	0.27	7.0
8	Sphere, 15 mm. radius	14	28	9	0.64	0.32	7.0
9	Sphere, 20 mm. radius.	33.5	50	18	0.54	0.36	Surface 7.0
10	Sphere, 25 mm. radius.	65.4	77.5	25	0.38	0.32	Surface 6.3

TABLE XXV

INTENSITIES FOR CORRECTED VOLUMES AND DOSES

A	B	C	D	E	F	G
No. of "Tumor"	Volume, C.c.	Area, Sq. Cm.	No. of Tubes of 1 Mc.	Mc. per C.c.	Mc. per Sq. Cm.	Minimum Intensity
3	2.9	10.9	4	1.38	0.37	10.5
4	5.8	19.6	6	1.03	0.31	10.3
7	13*	37	12	0.77	0.27	9.5
8	12*	28	9	0.75	0.32	7.0
9	22*	50	18	0.80	0.36	7.0
10	34*	77.5	25	0.74	0.35	6.3

* These volumes are for a shell 5 mm. thick, having the same external dimensions as the tumor.

tube more than necessary in the case of these two tumors. Incidentally we may point out how considerably the distribution of radiation is influenced by a change in the number of tubes used for a given tumor. In tumor number 3 the omission of one tube in five reduced the minimum intensity from 13.9 to 10.5 units; and in tumor number 4 changing the number of tubes from seven to six reduced the minimum intensity from 14.8 to 10.3 units. This may be one reason why sometimes inconsistent results are obtained in practice.

On account of the fact that for the large tumors the tubes were distributed in a shell 3 mm. from the surface, the volume of such a shell was used to calculate the millicuries per cubic centimeter (Table XXV). The values thus obtained agree better with those for small tumors, but still the agreement is not so good as that among the values for the millicuries per square centimeter. We may conclude, then, that the area is a better indicator of the dose required. Knowing that this ratio is in the neighborhood of 0.34 (see Col. F, Tables XXIV and XXV) we have a simple method of estimating dosage. Thus if we have a tumor whose external area is 15 sq. cm. we find that the total number of millicuries to be used is $0.34 \times 15 = 5.12$,—that is, five to six tubes of 1 mc. each. As a working formula then we may take

Number of 1 mc. tubes $= 0.34 \times$ area.

Care must be exercised, however, in determining the external area, otherwise incorrect results will be obtained. As a check one should calculate also the millicuries per cubic centimeter and compare the value with those given in the tables.

We may decide now what is the minimum intensity which can be relied upon to affect favorably tumors of the type here considered. Analysing the figures of Col. G, Tables XXIV and XXV, we find that the variation is not very great considering the difficulties of estimating dosage empirically. As previously stated, the millicurie doses for tumors numbers 3 and 4 are probably a little high. Tumors numbers 7 and 8 are thicker than the preceding ones, so that it was necessary to arrange the prescribed number of tubes in more than one plane. One or two additional 1 mc. tubes would improve the distribution and would increase considerably the minimum intensity. As to the last two tumors, it is doubtful whether the proper doses can be determined empirically on account of complications which usually accompany tumors of this size and type. It will be remembered that the large tumors in the group were assumed to be metastatic, and therefore the prognosis for such cases is very poor. Furthermore, one cannot overlook the effect on the patient as a whole of a large amount of buried radon which produces a great deal of necrosis.

In view of these considerations we feel that the practical minimum intensity of radiation necessary to affect favorably this type of tumor is in the neighborhood of 10 units* as defined above. In other words, the effective dose for this type of tumor is 10 per cent of the minimum dose required to produce necrosis in rabbit muscle. It should be noted that this conclusion is based on the use of buried radon to produce both the tumor effect and the muscle necrosis. If any other method is employed we cannot say what the ratio between the doses for the two effects would be.

Having decided on the proper value for the minimum intensity, we can determine the necessary dose and spacing of tubes for tumors of any shape and size. To do this we estimate first the number of tubes according to the surface area and volume of the tumor. Then by means of the curve of Figure 16 we arrange them so that the distribution of radiation is as uniform as possible, and we calculate the minimum intensity which results thereby. If this is lower than 10, the number of 1 mc. tubes to be used is increased until the proper minimum intensity is obtained.

We have made all our dosage calculations on the assumption that 1 mc. tubes are used for the treatments, since this is the strength commonly employed. If we wish, however, we can get the necessary dosage information for any other strength of the tubes, even if they are of different values in the same tumor. The data

* This really does not represent the intensity, but rather the quantity of radiation. In the present case, where the source of radiation is left in place permanently, the two are proportional.

developed in this paper are sufficient for the purpose. In this connection it may be well to investigate the effect of the strength of the individual tubes.

Taking the necessary minimum intensity of radiation as 10 units, we can determine the distance at which a tube of any strength (from 0 to 10 mc.) will deliver the minimum dose required to affect tumor tissue of the type here considered. We may call this the effective radius. The Figures of Col. B, Table XXVI, represent these radii. For comparative purposes

TABLE XXVI
EFFECTIVE RADII, AND RELATIVE VOLUMES OF NECROSIS

A	B	C	D	E	F
Mc.	Effective Radius, Mm.	Radius Necrosis, Mm.	Volume Affected, C.c.	Volume Necrosis, C.c.	Per Cent Volume of Necrosis in Affected Region
0.5	5.1	1.75	0.558	0.029*	5.0
1	6.2	2.75	1.00	0.092*	9.2
2	7.7	3.70	1.92	0.212	11.0
3	8.8	4.25	2.85	0.322	11.3
4	9.6	4.57	3.70	0.400	10.8
5	10.2	4.80	4.48	0.465	10.4
6	10.8	4.95	5.32	0.507	9.5
7	11.2	5.07	5.86	0.545	9.3
8	11.7	5.16	6.70	0.573	8.5
9	12.1	5.23	7.42	0.600	8.1
10	12.5	5.30	8.16	0.620	7.6

*For these radii the volumes are not spherical. Allowance has been made for elongation.

we give also in Col. C the radii of necrosis, as determined from the rabbit experiments. *Assuming that the same amount of necrosis would be produced in this type of tumor tissue*, we can determine the volume of necrosis as compared to the total volume which is effectively irradiated by a single tube of a given radon content. From butter discoloration experiments with tubes of the length ordinarily used in practice (3 to 4 mm.) we know that the affected region is very nearly spherical. Only when the region is very small is it elongated. The volumes of Col. E, therefore, were calculated for spheres of the radii given in Col. A, except for the first two, in which allowance was made for the elongation. In order to get a better idea of the relative volume of the necrotic and affected regions we give the figures of Col. F. Each represents the percentage volume of the total affected region which is necrotic.

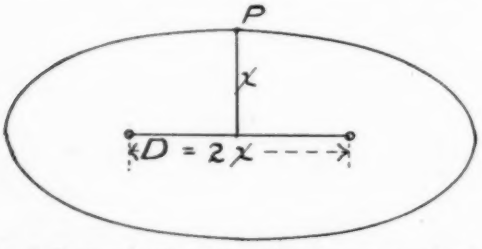


FIG. 18. Determination of spacing for two equal tubes.

It will be seen that from 1 to 9 mc. the percentage of necrotic tissue produced is approximately the same. For tubes of less than 1 mc. and more than 9 mc. there is *relatively* less necrosis produced. On this basis, therefore, it is advantageous to use for therapeutic purposes, tubes of less than 1 mc. or more than 9 mc. However other considerations must be taken into account. We do not feel that the experimental information embodied in the present paper suffices to decide what tube strength should be used in practice.

At the present time it is generally assumed that 1 mc. tubes should be placed 1 cm. apart. If we measure the distances between adjacent tubes in the hypothetical tumors for which we worked out the proper spacing, we find that they vary from 5 to 12 mm. according to the size and shape of the tumor. This is due to the fact that when a large number of tubes is used the dose at any point is the resultant of the amounts of radiation delivered by all the tubes. It will be seen, therefore, that if the tubes were placed 1 cm. apart in all cases, small tumors would be irradiated ineffectively, and large tumors would be overdosed. In the case where *only two* tubes are used, we have determined the spacing, assuming that an oval shaped volume, as shown in Figure 18, is to be treated. The distance D is adjusted so that the intensity at point P due to the two sources is 10 units. The values for different radon contents of the tubes are given in Table XXVII.

TABLE XXVII

DISTANCE BETWEEN TWO EQUAL TUBES, FOR DIFFERENT MILLICURIE VALUES

Mc.	Distance, Mm.
0.5	8.7
1	10.9
2	13.5
3	15.2
4	16.5
5	17.6
6	18.5
7	19.4
8	20.2
9	20.9
10	21.6

Another assumption which is ordinarily made is that the dose for a given tumor should be estimated at 1 mc. per cubic centimeter. According to the results of Col. E, Tables XXIV and XXV, this would also result in underdosage for small tumors and overdosage for large ones. As to the volume of necrosis produced by a 1 mc. tube, it is very far from 1 c.c., as will be seen from Col. E of Table XXVI. When a number of tubes is used, however, we may expect a larger relative amount of necrotic tissue due probably not directly to the effect of the radiation, but to other causes (blood supply, infection, etc.).

SUMMARY AND CONCLUSIONS

This paper relates to the therapeutic uses of fine glass tubes containing small amounts of radon, the tubes being inserted into a tumor and never withdrawn. This method has been employed extensively for a number of years but no suitable criterion for dosage has been available. The work described here was undertaken for the purpose of determining the amount of radon, the number of tubes and the spacing to be used in the treatment of epidermoid carcinoma occurring particularly in the mouth.

The problem was attacked in the following manner: Since the effect of radium radiations on living tissues is involved, the solution cannot be found by physical experiments alone. A quantitative study of the effects of radon tubes buried in a tumor is beset with many difficulties which preclude a direct determination of the proper dosage. Therefore, indirect means were employed. To begin with, the radiation emitted by the source and that passing through different thicknesses of tissue, was analyzed to establish the relative amounts of beta and gamma rays. At the same time the absorption of the radiation by tissue was determined. The information thus obtained permitted us to calculate, as a first approximation, the distribution of radiation in the tissue surrounding the radon tube.

The next step was to determine quantitatively the extent of a definite effect produced in a given type of living tissue by tubes of different strengths, left in place for various time intervals. The tissue chosen for this purpose was the dorsal muscle of the rabbit and the effect, the necrosis produced by the rays. Owing to marked variations inherent in such biological experiments, a large number of animals was used in order to obtain results with a reasonable degree of precision. From those an average curve was determined which represents the *probable* variation of the radius of necrosis with respect to the strength of the source, other conditions remaining the same. The curve enables us to predict the average radius of necrosis which would be produced in rabbit muscle under the conditions of our experiments, for a radon tube of any strength within the limits of the curve.

A parallel series of experiments was carried out using ordinary table butter as the medium and the discoloration produced therein by the rays as the measurable effect. A similar average curve was thus obtained representing the relation between the strength of the source and the radius of butter discoloration. Since much less work is involved in these experiments than in the rabbit experiments and the results are more definite, the investigation was extended in order to obtain more general information and additional data.

One cannot expect the results of the rabbit and butter experiments to agree very closely, inasmuch as the radiation effects involved are different. The chief difference, of course, lies in the fact that the destructive effect of the radiation on living tissue is counteracted by the repair process which tends to restore normal

conditions. The sensitivity of the two media to radiation must also be considered. However, when the time elapsed between the insertion of the tube and the examination of the tissue is relatively short, the repair process does not play a very important part. The influence of the different sensitivity of the two media can be minimized by considering the *relative* variation of the radii of action with respect to the strength of the source, instead of the observed radii. Under these conditions a fair agreement was found between the results of the two types of experiment.

As already stated, the calculation of the intensity of radiation at different distances from the buried source, gave a first approximation of the dose delivered to different points in the tissues. In order to get a better idea of the dose which was responsible for the observed effects, other experiments were planned. These enabled us to determine the intensity of radiation at any point in the range investigated, in terms of the effectiveness of the radiation in producing skin erythema. Thus it was possible to establish in terms of the erythema unit the doses required to produce the threshold necrosis at different distances from the source. It was found that the necessary number of erythema doses increased considerably with the distance. This result may be attributed largely to the difference in the quality of radiation at the different points. It leads to the conclusion that soft beta rays are more effective in producing muscle necrosis than they are in producing skin erythema. On the other hand, hard beta rays and gamma rays are more effective in producing skin erythema than they are in producing muscle necrosis.

By suitable treatment of the experimental data thus obtained we can determine the resultant dose of radiation at any point in a given volume of tissue in which radon tubes have been embedded. The dose can be expressed in terms of the skin erythema effect or the muscle necrosis effect—the numerical value of the dose, of course, being different for the two. This permits a correlation of dose and effect in tumors treated by this method. If then we know from clinical experience the amount of radon and the number of tubes required to treat successfully a given tumor, we can determine the tissue dose which was responsible for the disappearance of the tumor. Owing to the fact that a limited number of discrete sources is employed in practice, the distribution of the dose of radiation within the tumor is very uneven. There are certain points in the tumor mass, therefore, which receive less radiation than any others. We may take the dose at these points as the practical minimum required to obtain the desired result.

In order to establish this practical minimum dose with greater accuracy we determined it for ten hypothetical tumors of different shapes and sizes. The amount of radon and the number of tubes to be used for each were prescribed by Dr. Douglas Quick, from clinical experience. The tubes were arranged so as to give the most uniform distribution of radiation within each tumor and the minimum dose was determined. The results were then analyzed and it was found that a slight variation in the millicurie doses for some of the tumors would bring the calculated minimum doses very close together for all the tumors except the largest two. We thus obtained the most probable value for the practical minimum dose required for the type of tumor here considsred (epidermoid carcinoma). With this additional information it is possible to determine the total amount of radon, the number of tubes and the proper distribution to treat effectively a tumor of this type of any shape and size.

Certain results of some practical value were obtained as by-products of the main solution. Thus it was found that the approximate amount of radon required to treat a given tumor can be calculated by the relation:

$$\text{Number of 1 mc. tubes} = 0.34 \times \text{area}$$

where by "area" is meant the total surface area of the tumor. To use this relation one should make a model of the tumor to be treated, using a plastic material like dental compound, and then estimate the area as closely as possible. The number of millicuries per cubic centimeter of irradiated tissue depends on the size and shape of the tumor. The approximate value for any given case can be obtained by comparison with the values for our hypothet-

ical tumors. Similarly the desirable distribution of 1 mc. tubes can be ascertained from our models. The effective radius, the radius of necrosis and the relative volume of necrotic tissue in the affected region, are tabulated for tubes of different strength.

In conclusion, we may say that the tumor dosage data worked out in this paper are ultimately based on the millicurie doses recommended by Dr. Quick for our ten hypothetical tumors. The fact that the calculated minimum intensities for practically all these tumors, agree as well as they do, is a good indication that the prescribed doses are at least approximately correct for the type of tumor considered. Accordingly the results of any dosage calculations based on the data we give, cannot be far wrong, if no additional assumptions are made. The results relating to the dose of radiation delivered at different distances from the source are, of course, independent of the data supplied by Dr. Quick. It may be well to mention here that the proper distribution of the radon tubes in a tumor is more important than the correctness of the total amount used. The data relating to the effective radius of tubes of different strengths, the calculated spacings between two such tubes, and the volume distribution of the prescribed tubes in the ten hypothetical tumors, will be found of some value in this connection.

The authors wish to express their indebtedness to Dr. Raymond Hussey for his kind cooperation and interest in the conduct of the animal experiments, and to Dr. Douglas Quick for the clinical information used in the paper. Thanks are also due to our laboratory assistants for the careful way in which the many special tubes used in the course of the work, were prepared.

REFERENCES

1. Failla, G., Quimby, E. H., and Dean, A. Some problems of radiation therapy. Am. J. Roentgenol., 1922, ix, 479–497.
2. Janeway, H. H. Treatment of cancer, particularly of the tongue, tonsil, and rectum, by buried emanation. Am. J. Roentgenol., 1920, vii, 92–101.
3. Bagg, Halsey J. The action of buried tubes of radium emanation upon normal and neoplastic tissues. Am. J. Roentgenol., 1920, vii, 536–544.
4. Lacassagne, Antoine. Recherches experimentales sur l'action des rayonnements beta and gamma du radium agissant dans les tissus par radiopuncture. *J. de radiol. & d'électrol.*, 1921, v, 160.
5. Quimby, Edith H. Comparison of different metallic filters used in radium therapy. Am. J. Roentgenol. & Rad. Therapy, 1925, xiii, 330–342.

THE TREATMENT OF EPITHELIOMA OF THE PENIS WITH RADIUM AND ROENTGEN RAYS*

BY ARCHIE L. DEAN, JR., M.D.

From the Department of Urology, Memorial Hospital

NEW YORK CITY

THE purpose of this paper is to describe a method of treating carcinoma of the penis which is based upon the treatment of 56 cases from the Department of Urology of the Memorial Hospital, together with 5 additional cases from the general radium service which I include with the permission of Dr. Douglas Quick.

Epithelioma of the penis is a disease which begins insidiously, progresses locally with some celerity, metastasizes with regularity, and unless entirely cured causes death.[1]

The usual etiological factor is the chronic irritation beneath a tight prepuce. The tumor may be papillary or flat. Each type infiltrates, each may become ulcerated, and each by microscopic examination is squamous cell carcinoma.

The disease progresses by steadily involving a greater surface area, and also by infiltrating deeper structures. In this latter direction, however, there is an important natural barrier, namely Buck's fascia. Before this fibrous tissue has become penetrated the growth is truly superficial. After the cavernous erectile tissue has become involved, the therapeutic problem is more complicated and the prognosis is correspondingly less encouraging.

Metastasis is by embolism, the earliest extension usually being found in the inguinal lymph nodes. Later, the deep pelvic nodes may become invaded by way of the lymphatics which accompany the dorsal vein of the penis. Because of the infection which so regularly is present in and about tumors of the glans and prepuce, some degree of inguinal adenopathy is usually present, whether or not metastases have occurred.

During the course of radiation therapy it is of the utmost importance that the primary tumor be kept clean and dry so that the element of infection with its accompanying irritation may be eliminated. Slitting the prepuce without cutting into tumor areas is frequently sufficient to obtain necessary exposure. A complete circumcision previous to irradiation should be undertaken only after careful examination gives assurance that it can be accomplished without traumatizing the tumor. We attempt to clean the exposed lesion by gently washing with soap and water, frequent soakings in warm 1:5000 potassium permanganate solution, and administering gradually increasing doses of light from the quartz lamp.

To date we have obtained more satisfactory regression of the primary tumors with radium than with roentgen rays, and in the majority of cases the radium applicator is less tedious to adjust.

If the growth is superficial and Buck's fascia is intact, we expect surface irradiation alone to result in a permanent regression. The applicator employed is made from an impression of the tumor in dental modeling compound. Radium emanation tubes of approximately equal strength, encased in cylinders of silver 0.5 mm. thick are arranged in the mould so that they will be 1 mm. from the surface of the lesion. The usual dosage is 65 mc-hr. to each square centimeter of tumor surface.

If the deeper structures of the organ have become invaded by extension of the disease, we apply the same type of treatment but increase the dosage in proportion to the depth of tumor tissue.[1] Then, after sufficient time has elapsed to permit the effects of the irradiation to become established, usually two to four weeks, amputation is performed in a plane one to two centimeters from the proximal edge of the tumor.

We believe this conservative type of operation to be an important part of our

[1] For a more complete discussion of the clinical features of the disease see Epithelioma of the Penis, Barringer and Dean. *J Urol.*, 1924, xi, 497–514.

[1] See Table 1 for the computation of doses of radium emanation for different thicknesses of tumor.

* Read at the Tenth Annual Meeting. AMERICAN RADIUM SOCIETY, Atlantic City, N. J., May 25–26, 1925.

therapy in these advanced cases because it promptly ends the element of pain and removes the dangers of further infection and metastasis.

Recognition of the fact that metastasis along the lymph channels is by embolism rather than by permeation renders the radical emasculating operation obsolete except in the most extreme cases, and our results demonstrate that after a really efficient irradiation, little more of the penis need be sacrificed than has already been destroyed by the disease.

The inguinal lymph nodes are treated in all cases with roentgen rays. The radium pack, previously employed, is more expensive, less commonly available, and of no greater efficiency as gauged by clinical observation or physical computation. Our routine requires the irradiation of the groins of all patients whether or not there are definite signs of metastasis.

Because of the highly radioresistant nature of primary squamous cell carcinoma and its metastases, maximal irradiation must be given. For this reason the groin exposures are repeated as soon as skin toleration will permit.[1]

After the primary lesion has been controlled and the groins have been thoroughly irradiated, if inguinal adenopathy disappears, treatment is suspended. The patient is seen at intervals of two weeks, and any further therapy is based upon the findings of these examinations.

Managed in this way, we have never seen metastatic lymph nodes develop in an area which had been considered free from disease at the time the patient came under our care.

RESULTS

Our results to date may be classified in the following groups which are based upon the extent of the disease found at the first examination.

GROUP 1. *Superficial local lesion without metastases; 6 cases.* All of these patients were treated with surface irradiation only. Five, or 83 per cent are known to be living without sign of disease, one year, one year and five months, three years and five months, four years and two months, and five years and eight months, respectively, after the first irradiation. One patient was lost from the records a year after his first treatment, at which time he was apparently free from disease. A typical case history follows:

Patient T. H. (M. H. 29852), an Irish carpenter sixty-six years of age, was referred by the Presbyterian Hospital, October 26, 1921. The man stated that a small sore had appeared on the left side of the glans penis in October, 1920 (a year previously), and that it had been growing larger in spite of local applications. At present sharp and burning pain is felt. A biopsy had been performed.

Dr. Ewing made the following report:—"Sections received from the Presbyterian Hospital, and returned to them, show all phases of epidermoid carcinoma except infiltration of tumor cells through the dense fibrous capsule of the glans. There is a marked thickening of the epidermal layer with papillary projections two to three millimeters high. The cells are very atypical with hyperchromatic nuclei and irregular arrangement. The rete pegs dip down in long strands but fail to penetrate the capsule. There are many pearls, some hornified. Many small lateral buds of atypical cells appear along some pegs. The case is one of diffuse superficial papillary epithelioma without infiltration."

Gross examination of the lesion revealed on the left side of the dorsum of the glans penis a round, raised, succulent, pink growth scabbed over in spots and measuring 2.5 by 3.5 cm. (Fig. 1). No induration could be felt beneath or proximal to the edge of the tumor. Inguinal adenopathy was present on either side, more on the left than on the right, but in neither situation were the characteristics of carcinoma metastases found.

The primary lesion was immediately treated with a dental compound applicator, and received 60 mc-hr. per square centimeter of tumor surface, filtered through 0.5 mm. of silver. Three months later an area 3 mm. in diameter was found which evidently had been insufficiently irradiated. A single silver tube was laid on this spot until 61 mc-hr. had been administered. Each groin received a rather weak low voltage roentgen-ray treatment.

As shown in Figure 2, taken seven months later, disappearance of the lesion was prompt and complete. At no time did the patient complain of pain as the result of his treatment. To date, three years and six months later, there has been no sign of recurrence, and no other treatment has been given.

[1] See Table II for factors employed when irradiating tumors at different depths below the skin surface with roentgen rays.

GROUP 2. *Extensive local tumor without metastases; 30 cases.* Of these, 21, or 70 per cent, are known to be living, 7 between three months and one year, 3 between one and two years, 3 between two and three years, 2 between three and four years, and 6 between four and five years.

Five patients are known to be dead, one of postoperative uremia, one of pneumonia a year after irradiation, one of an unknown cause three years and eight months after irradiation, and 2 of a direct extension of the disease, operation having been refused. Four patients were lost from the records, one month, one year and one month, one year and eleven months, and three years and three months, respectively, after the first irradiation.

FIG. 1. Superficial epithelioma of the penis (patient T. H.).

FIG. 2. Same as Figure 1, seven months later.

The following is an illustrative case history:

G. S. M. (M. H. 31274), a negro cabinet maker thirty-eight years of age, was referred from the Cornell Clinic June 12, 1922, after a biopsy had been performed. The patient stated that nine months previously (October, 1921), a small, red, raised spot had appeared on the end of his penis near the meatus. This grew steadily in size. Two months ago ulceration occurred and the sore became painful.

Physical examination revealed an ulcer of the glans penis which involved the distal two-thirds of the left side. The surface was raised a few millimeters in spots, and here the impression was gained of a low papillary lesion. Induration was marked, and could be felt extending some distance beneath the edges of the tumor. Bilateral inguinal adenopathy was present, but it was attributed to secondary infection, syphilis, or both. The Wassermann reaction was strongly positive.

The penis lesion received an irradiation of 61 mc-hr. per square centimeter, filtered through 0.5 mm. of silver, applied by means of a dental compound applicator. The groins were treated with low voltage roentgen rays.

Regression in the size of the primary tumor occurred but it was slow. The pain, of which the patient complained at the time of admission, was not relieved, and as a result the man's general condition was so depreciated that five months after the radium application, the glans penis was removed. No further treatment has been given, the patient is enjoying excellent health, and there are no signs of recurrence.

The specimen removed at operation was classified by Dr. Ewing as "papillary and infiltrating squamous carcinoma."

GROUP 3. *Extensive local tumor with groin metastases; 16 cases.* Four, or 25 per cent of these patients are known to be

living, one year, one year and two months, two years and four months, and three years and seven months, respectively, after irradiation. We do not know with certainty whether or not these patients are entirely free from disease.

Seven of this group are known to be dead, their average length of life after irradiation being eighteen months. Five patients are lost from the records. We assume that they are dead. The following case report illustrates the problem of this group:

FIG. 3. Advanced papillary type of squamous cell carcinoma at time of admission.

FIG. 4. Same as Figure 3, showing regression after surface irradiation. This is a favorable time to perform a local amputation.

J. S. (M. H. 30628), a fifty-eight year old German chauffeur was referred from Bellevue Hospital after a biopsy had been performed, and the diagnosis of squamous carcinoma had been made. The man complained of a painful sore which had been present on the glans penis for eighteen months. Recently, swelling and pain had become so marked that he desired medical attention. Physical examination revealed the right side of the glans penis and the overlying prepuce involved in a low, papillary, ulcerated growth with induration of the base palpable to the depth of one centimeter. Many enlarged, hard, and fixed lymph nodes were present in each groin.

After a dorsal slit had exposed the entire lesion, radium emanation was applied in a dental compound applicator, using 60 mc-hr. to the square centimeter, and low voltage roentgen rays were directed over the inguinal metastases.

While a certain amount of regression in the size of the primary tumor occurred, complete healing never took place, and infection was a constant feature. The size of the inguinal nodules slowly increased. Four months after the radium application it was deemed advisable to perform an amputation, and the distal third of the penis was removed. In spite of the fact that four courses of roentgen therapy were applied to the groins, the metastases grew larger, fungated, and caused the patient's death two years and one month after the beginning of his treatment.

A propos of our exceedingly high mortality in this group composed of those patients who presented themselves with advanced penis lesions and inguinal metastases, the importance of the element of infection may well be stressed once more. While a conscientious surgeon hesitates before operating upon a primary cancer when obvious metastases are present, and we believe that this should never be done without a pre-operative irradiation, nevertheless it is essential, in the case of penis cancer with metastases, that the source of

infection be removed as promptly as possible. We have found after many unhappy experiences that no type of irradiation with which we are familiar is capable of appreciably retarding the growth of squamous cell carcinoma in lymphatics which are simultaneously draining infected areas.

GROUP 4. *Postoperative recurrences;* 8 *cases.* Of these patients, 3, or 37.5 per cent are known to be living and free from signs of disease, four years and one month, four years and six months, and five years and three months, respectively, after their first irradiation.

Three patients are known to be dead. The average survival period was one year and one month after the first irradiation. Two patients are lost. Each was known to be living one year after treatment.

W. W., a forty-six year old English chauffeur visited Bellevue Hospital in September, 1919, with symptoms of four months' duration. A small sore had appeared near the meatus which gradually grew until it obstructed the flow of urine, and involved nearly the entire glans. Each groin was the site of metastases. A radical amputation was performed and the inguinal nodes on each side were removed. Squamous cell carcinoma was found in sections from all three areas. Two months later recurrences appeared beneath the inguinal scars and the man was referred to the Memorial Hospital. Four courses of low voltage therapy were given extending over a year. Today the patient is in good health, working regularly, and shows no evidence of disease.

5. For postoperative irradiation as a prophylaxis against recurrences; one case.

This patient was operated upon at another institution where a radical amputation of the penis was performed together with a bilateral dissection of the inguinal lymphatics. Carcinoma was found in all three areas by microscopic examination. He was immediately referred to the Memorial Hospital. Low voltage irradiation was applied to the limit of skin tolerance. The man is now living without signs of disease three years and two months after his first treatment.

DISCUSSION OF THE RESULTS

The good results obtained with surface irradiation upon the superficial tumors of Group 1 demonstrate how amenable these early cancers are to radium therapy. No cicatrization followed the treatments, and no function was inhibited. This is another instance of the desirability of beginning cancer treatment during the early stages of the disease.

When the growth extends to the deeper parts of the penis, amputation after irradiation appears to be necessary. This situation exists even though our endeavor has been to devise a type of radiation which unaided will effect a cure. All of the favorable cases in Group 2 were operated upon after irradiation. The disastrous cases refused operation and were treated with radium alone. We believe that pre-operative irradiation has definite value in that it permits a more conservative operation with less likelihood of local recurrence.

Therefore, on the basis of our experience, thorough irradiation of the penis and groins, followed by amputation, is the method of choice in managing these patients.

There is evidence for believing that we have been too conservative in the treatment of those patients who have presented themselves with an advanced penis lesion and inguinal metastases. An attempt was made to withold all operative interference and resort to irradiation alone. The results show the futility of this course.

The method we now employ consists of promptly removing the tumor-bearing portion of the penis after a thorough irradiation of both this area and the groin metastases. With the primary tumor eliminated, subsequent measures are dependent upon the success of roentgen irradiation in retarding the development of the inguinal metastases. If the element of infection has not already become too well established, the nodules will decrease in size, and evidence exists (Group 4) that frequently repeated irradiation may result in their complete disappearance. In some cases, however, inguinal dissection is necessary.

A close analogy exists between the inguinal metastases of penis cancer and the cervical metastases of intraoral carcinoma. In respect to the latter condition, many data are at hand to show that after high voltage roentgen rays have been thoroughly applied it is possible to remove the metastatic nodes by surgery. The advantage of

the pre-operative irradiation, in addition to the signs of clinical improvement, is particularly demonstrated by the microscope. In many instances all growth properties of the cancer cells have been destroyed, and frequently such a degeneration has resulted that no frank carcinoma can be found.

A type of irradiation which has been discarded in so far as penis cancer is concerned, is that of burying emanation tubes or seeds in the primary tumor and also in the nodules of the groin. Subsequent amputations have given the opportunity to study their effects. The site of each implanted tube was marked by a spherical cavity approximately one centimeter in diameter and largely filled with caseous débris. While quite successful in its destructive effects upon the tumor tissue, this type of irradiation was painful, and was no more conservative than operative interference. In addition the cosmetic results were bad.

When buried in metastatic nodules much reaction followed, and in some cases, perhaps due to superimposed infection, sinuses developed through which carcinoma rapidly progressed to the skin.

TABLE I

INTENSITY OF RADIATION DELIVERED TO VARIOUS DEPTHS IN A TUMOR SURROUNDED BY A RING OF RADIUM TUBES

(Filter 0.5 mm. silver; tubes about 2.5 mm. from skin)

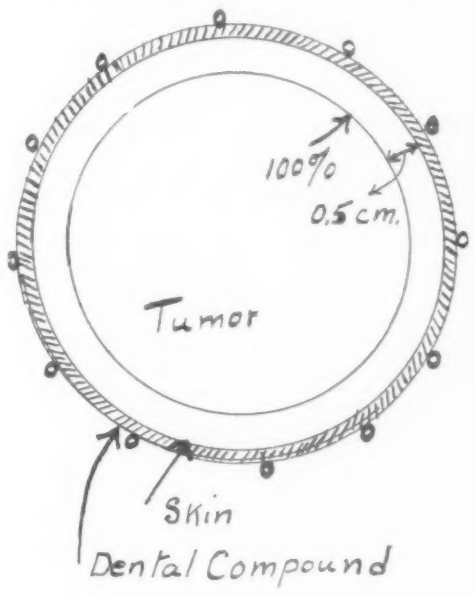
A Penis Diameter, Cm.	B Depth Cm.	C Per Cent of Surface Dose Reaching Depth	D Number of Full Surface Doses Necessary to Deliver One Full Dose at Depth
3	0.5	100	1.0
	1.0	94	1.06
	1.5	90	1.1
5	0.5	100	1.0
	1.0	90	1.1
	1.5	81	1.2
	2.0	77	1.3
	2.5	76	1.3
8	0.5	100	1.0
	1.0	85	1.2
	1.5	73	1.4
	2.0	66	1.5
	2.5	62	1.6
	3.0	58	1.7
	3.5	57	1.8
	4.0	56	1.8

If 65 mc-hr. per square centimeter is a full therapeutic dose, effective at a depth of 0.5 cm., the numbers in column D indicate the number of such doses per square centimeter which must be given to deliver effective radiation at greater depths.

DOSAGE TABLES

Table I represents the amount of radium radiation necessary to employ in treating penis tumors of different sizes. The tumor diameters of 3, 5, and 8 cm., respectively, shown in column A, represent three sizes of the penis affected with cancer. Column B represents different depths to which the tumor has invaded. The last figure in this column for each group is the center of the penis.

We believe from clinical observation, that a dose of 65 mc-hr. per square centimeter is an adequate treatment for a tumor 5 mm. in depth. Therefore this was the amount of radiation considered as minimal and therapeutically reasonable to deliver to all parts of the tumor. If the growth is a superficial one, and is but 5 mm. deep, it probably could be treated simply with a surface applicator, and no operation would be considered. On the other hand, if it were a centimeter deep, it would be necessary to sacrifice the affected part of the penis after irradiation. Because the amount of surface irradiation is multiplied so many fold when a single applicator is employed in the endeavor to deliver an effective dose to a depth (see Table III), and because we



know practically that the part of a penis affected with a deeply infiltrating tumor must be removed, we decided that it would be more convenient to administer the pre-operative irradiation to a deep penis tumor by using several portals of entry; in other words, to surround the penis at the level of the cancer with emanation tubes enclosed in 0.5 mm. of silver. The figures of columns C and D, therefore, depend upon the fact that every part of the growth is exposed to the same amount of radiation that has proven effectual for surface lesions, namely 65 mc-hr. per square centimeter.

TABLE II

COMPARISON OF PENETRATING POWER OF ROENTGEN-RAYS FROM TWO MACHINES

Depth, Cm.	Percentage of Surface Dose Delivered at Depth	
	I 140 Kv. Peak 15 In. Distance 5 Mm. Al Filter (Dose is 25 Min.)	II 200 Kv. Peak 20 In. Distance 0.5 Mm. Cu Filter (Dose is 80 Min.)
0	100	100
1	98.0	99.0
2	91.5	93.0
3	80.0	87.0
4	76.5	80.6
5	62.3	77.0
7	46.0	56.6
10	30.8	38.0
15	14.4	20.7

In the case of W. W., less than 250 per cent of a skin erythema dose, spread over one year (four treatments) was sufficient to cause a 5½ year regression in metastatic inguinal lymph nodes approximately 3 cm. below the skin surface. This radiation was delivered with lower voltage, less filtration, and shorter target-skin distance than in I above.

TABLE III

DEPTH DOSES FROM DENTAL COMPOUND APPLICATOR
(Circular applicator 4 cm. in diameter)

A Depth, Cm.	B Per Cent of Surface Dose Reaching Depth	C Number of Full Surface Doses Necessary to Deliver One Full Dose at Depth
0.5	100	1.0
0.75	79	1.3
1.0	64	1.6
1.25	52	1.9
1.5	46	2.2
1.75	39	2.6
2.0	34	3.0

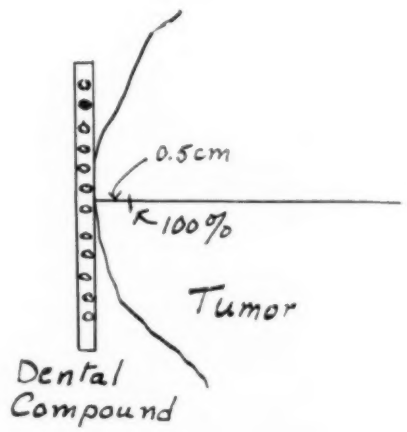
If 65 mc-hr. per square centimeter is a full therapeutic dose, effective at a depth of 0.5 cm., the numbers in column C indicate the number of such doses per square centimeter which must be given to deliver effective radiation at depths.

Column C indicates the percentage of this treatment which is delivered to the depths indicated. This was determined experimentally with the ionization chamber. Column D shows the number of surface doses of 65 mc-hr. per square centimeter that must be given to deliver this dosage to tumors of the depths tabulated, the radium tubes being arranged as diagrammed.

Therefore if a patient presents himself with a tumor 2 cm. deep on a glans penis 5 cm. in diameter, we know by consulting the table that one surface application of 65 mc-hr. per square centimeter to the tumor will deliver only 77.2 per cent of this dose to the deepest part, and that to give the required amount of radiation to all parts of the tumor we must fix our radium tubes around the penis, and give a surface application of 1.29 per cent of this dose, or 83.95 mc-hr. per square centimeter.

Table II may be used as a guide in determining the proper doses of roentgen rays to apply to metastatic inguinal or pelvic tumors. Here has been tabulated the percentage of the skin dose which is delivered to tumors situated at different depths. Also the relative efficiency of the high and low voltage types of therapy is indicated. The factors used are those we most commonly employ in the treatment of the groins. It may be seen that the high voltage machine is more efficient at all depths, and since for our purpose maximal irradiation is required, it is preferable, if available.

An effort was made here as with the primary lesion to ascertain a proven effectual dose, but with less success. The cases



apparently cured of known inguinal metastases are fewer, and were treated with factors not employed today, for which no ionization chamber experiments have been performed. The patient W. W. described in Group 4, received something less than 250 per cent of a skin erythema dose extending over a year, but this figure is too vague to be of practical importance. Until more material is available the safest procedure is to administer as much treatment as the skin will tolerate, and by slanting the Coolidge tube, employ as many portals of entry as possible.

SUMMARY

1. In the treatment of primary epithelioma of the penis and also of its metastases, the element of infection must be eliminated as promptly as possible.

2. A superficial epithelioma of the penis should undergo a complete regression when treated with a surface applicator of radium emanation, and a dose administered of 65 mc-hr. per square centimeter filtered through 0.5 mm. of silver.

3. If the penis tumor has invaded the cavernous tissues, thorough irradiation followed by a local amputation is the treatment of choice.

4. We believe that the pre-operative irradiation of a penis carcinoma permits a more conservative type of operation to be performed, and with less danger of a local recurrence.

5. The most convenient and least traumatizing method of thoroughly irradiating a deep penis tumor is to apply surface applicators of radium emanation around its circumference.

6. On the basis of a proven effectual dose, a table is presented which indicates the amount of surface irradiation required to treat penis tumors of different depths.

7. In some instances irradiation with roentgen rays is sufficient to cause the disappearance of inguinal metastases.

8. If, after full doses of roentgen rays have been given, the metastatic nodules do not steadily decrease in size, in firmness, and in their degree of fixation, and the cause of this delay cannot be attributed to infection, careful dissection of the involved nodes is indicated.

9. The high voltage type of roentgen radiation is more efficient than that delivered by the low voltage machine for the treatment of metastatic nodules of all depths. This is indicated in Table 11.

10. With high voltage roentgen-ray machines available, it is unnecessary to depend upon the radium pack for administering deep therapy.

MALIGNANT TUMORS OF THE TESTICLE; DIAGNOSIS, PROGNOSIS AND TREATMENT*

BY EDWARD L. KEYES, M.D.

NEW YORK CITY

MALIGNANT tumors of the testicle are generally looked upon, following Ewing's classification, as teratomatous. These tumors are encountered in comparatively young men, the majority of them between the ages of twenty and forty, and fully half of them under thirty years of age. The tumor is recognized as one of the most malignant we know. I have seen approximately 30 patients afflicted with this disease and, with one exception, under the surgical treatment exclusively employed up to about ten years ago, I have not known a case to survive three years from the time the diagnosis was made and the testicle removed. This one patient survived more than twenty years. The testicle was removed by my father and reported sarcomatous by Dr. Wm. H. Welch.

The opinions of those who have written on this subject are at one as to the youth of the sufferers, the malignancy of the disease, and the comparative futility of operation. Yet the patient when first seen sometimes reports that his testicle has been enlarged for a number of years. It is therefore quite probable that in the future cases will be diagnosed by the alert physician sufficiently early to promise relief by orchidectomy before the malignant growth has extended beyond the testicle and its immediate surroundings. Yet at best, such an early diagnosis may be hoped for only in exceptional cases. Even the modern health examinations will not bring in many, for the tumor develops at an age when health examinations are scarcely thought of and the entirely insensitive increase in size of one of the testicles escapes notice until the more rapid growth occurs which is evidence of active malignancy within the testicle and which is accompanied by lymphatic and venous extensions. Thus Tanner[1] reports 600 cases, nearly all treated by orchidectomy alone; 465 of these were followed; 378 died of the disease; 25 were well four years after operation, a mortality of 96 per cent. More recently Handfield-Jones[2] has reported 22 personal cases of orchidectomy (without an abdominal operation) of which 4 were untraced; 2 were alive with metastases; 5 were dead (one after 4½ years, of tuberculosis; one after 7½ years of unknown cause); and 11 were alive and well, 4 of them having been followed four years (one for 8½ and one for 10½ years). No other surgeon has reported results even approximating these.

Such being the case, the hope for the sufferer from tumor of the testicle is: (1) An earlier diagnosis as already alluded to; (2) a more extensive operation; and (3) treatment by radiant energy or other accessory measures.

DIAGNOSIS

The tumor begins in the rete testis, in the region of the junction of the upper part of the epididymis with the back of the testicle.

As seen by the clinician, it develops in one of five different types which, in my practice, have occurred in the following order of frequency:

1. Syphilitic type
2. Hematocele type
3. Hydrocele type
4. Tuberculous (epididymitis) type
5. Cryptorchid type

1. *Syphilitic Type.* The testicle and epididymis are more or less distorted by tumor masses which produce an enlargement of varying density, imitating very closely the physical characteristics of the sclero-gummatous lesions of the testicle. Syphilis may be suspected from the history, and so far as my experience goes, the Wassermann reaction is a safe guide for primary diagnosis, to be supported by the effect of antisyphilitic therapy. The one patient whom I have seen with a teratoma of the testicle and a positive Wassermann reaction was operated upon for tumor after a brief delay to satisfy ourselves that a few injections of arsphenamine did not influence the growth.

* Read at the Tenth Annual Meeting, AMERICAN RADIUM SOCIETY, Atlantic City, N. J., May 25–26, 1925.

2. *Hematocele Type.* The testicle and epididymis are lost in a phlegmonous mass. The history of trauma does not help us. The Wassermann reaction is negative. The tumor does not transilluminate. Such testicles should be treated as tumors, on the basis that it is wiser to waste radiation upon a hematocele before operation than to regret afterward.

3. *Hydrocele Type.* Until one has plunged a needle into a teratoma of the testicle under the impression that it is a hydrocele, it is perhaps impossible really to appreciate how precisely a rapidly-growing cellular tumor can imitate all of the characteristics of a hydrocele, except that of translucency.* Hence the absolute rule that the diagnosis of hydrocele should always be confirmed by transillumination before it is operated upon or even aspirated.

4. *Tuberculous Type.* I have seen 3 cases so early that the tumor was confined to the region of the rete and had extended into the epididymis in such a way as to suggest tuberculosis (or chronic epididymitis).

Also, the tumor sometimes extends upward within the veins of the pampiniform plexus in the fascia immediately surrounding these, forming a dense cord that may be mistaken for a tuberculous thickening of the vas deferens, though the tumor mass may not involve the vas, which can then be felt as a separate, thin cord behind it. Such cases have been mistaken for tuberculosis. The diagnosis can perhaps not be assured immediately in all instances but a few weeks' observation should prove it.

5. *Cryptorchid Type.* The tumor grows in the testicle, either in the groin or in the pelvis. In one case (at Bellevue Hospital) the patient had an acute gonorrhea and a rather rapidly growing swelling in the left groin, and the left testicle was absent from the scrotum. Abscess of the left epididymis was diagnosed. This abscess was incised and pus obtained, but the wound did not heal and a subsequent biopsy disclosed tumor.

An abdominal testicle afflicted with tumor shows itself as a rapidly growing, extensive, inoperable pelvic tumor. I have known such a case to be reported as a sarcoma of the bladder. The mistake was unimportant since in any case, the patient was incurable. I do not know that teratoma in an abdominal testicle has been controlled by any form of treatment, yet the notion that the abdominal testicle is peculiarly liable to tumor formation has no extensive statistics to support it.

This brief summary of the present clinical situation as to diagnosis of teratoma may form the basis of our judgment as to the prospect of improvement in our treatment of the disease by early diagnosis. I can do no more than hopefully call the attention of medical examiners in general to the importance of palpating the testicle with sufficient precision to permit an occasional diagnosis of tumor at its earliest and most curable stage, while we must discourage vehemently the diagnostic aspiration of supposed hydroceles and the removal of supposed syphilitic testicles or hematoceles without consideration of tumor.

RADICAL OPERATION

The so-called radical operation for tumor of the testicle consists in supplementing the incision in the scrotum, through which the testicle is to be removed, by a second incision extending from just above the groin (in order to spare the iliohypogastric nerve) upward to a point opposite the umbilicus, or a little higher. The peritoneum is not entered but is lifted up until the whole length of the cava below the renal vessels is disclosed. The spermatic veins are then freed from the peritoneum and are removed in one mass with all the surrounding fascia between them and the great vessels. This operation, though no more tedious than the dissection of an axilla and with a far less mortality than the operation of Wertheim for carcinoma of the uterus, has no more brilliant record than the latter. I have performed it three times and have not in any case found tumor tissue in the mass removed, and during the period of my enthusiasm I saw several cases with palpable abdominal lymphatic metastases, from teratoma of the testicle, that were obviously inoperable, so that I cannot feel that my enthusiasm for this operation has profited a single patient, and I know that

* Dean notes that as a hydrocele grows, it pulls upon the skin of the penis and causes an apparent retraction of this, which tumor does not.

the retroperitoneal infection, following such an operation performed by one of my associates, hastened one patient's demise.

Hinman has supported this procedure more enthusiastically than anyone else in this country. Hinman, Gibson and Kutzman[3] report 79 patients upon whom the so-called radical operation was done, removing the testicle and the spermatic veins up to their entrance into the cava (or renal vein) together with all the lymph nodes between the spermatic veins and the cava. They classify these cases under four headings:

1. Those in which abdominal glands were palpable before operation (incurable by operation).
2. Inoperable conditions other than the above found at the time of operation.
3. Lumbar or pelvic carcinomatous nodes found and removed at operation.
4. No carcinomatous nodes found.

Table 1 shows that 21 of these cases were actually inoperable and that of the remainder 29 were alive and well at the time of report, 6 of them having been followed for four years.

It is to be noted that even so extensive an operation finds malignant nodes within the abdomen to be removable in only a little over 50 per cent (26 *vs.* 22) of cases.

TABLE 1

	Glands Palpable	Glands Inoperable	Glands Removed	Glands Not Found	Unclassified
Cases	9	13	26	25	6
Operation mortality	3	2	2	3	
Died of metastases	5	4	6	8	
Living with metastases	1	4	0	1	
Living and well	..	..	17	12	

COLEY'S TOXINS

Toxins, on the other hand, have been employed regardless of intraabdominal metastases.

Coley[4] reports 78 cases upon whom operation and toxins (with one exception) were employed. He enumerates the following 22 survivals for four years and more:

1. Well 14 years (toxins)
2. Well 11 years (toxins)
3. Well 8 years (toxins) (died of influenza)
5. Well 15 years (toxins)
6. Well 7 years (toxins)
7. Well 8 years (toxins)
9. Well 17 years (toxins)
10. Well 5 years (toxins and radium)
11. Well 5½ years (toxins)
13. Well 4 years (no toxins)
14. Well 14 years (toxins—then recurrence in opposite testis)
16. Well 10 years (toxins)
1a. Well 4 years (toxins) (then died of nephritis)
2a. Well 15 years (toxins)
3a. Well 10 years (toxins)
1b. Well 11 years (toxins)
2b. Well 12 years (toxins)
3b. Well 9 years (toxins)

RADIANT ENERGY

Doubtless no one advocates the treatment of neoplasm of the testicle exclusively by radium or by high voltage roentgen rays. The original site of the tumor is so accessible and the temptation to obtain a specimen for microscopic verification so great, that the application of treatment by radiant energy to teratoma of the testicle may be considered to imply surgical removal of the testicle. I am not qualified to discuss the relative merits of radium and high voltage roentgen rays before this body of specialists. Let me rather take shelter under the protection of the staff of the Memorial Hospital where I have obtained my notions upon this subject and from which has recently come a report by Dean, which includes some observations upon cases of mine and expresses conclusions with which I am entirely in sympathy.

My conviction as to the value of radiation treatment dates from 1916, when a patient applied to me, utterly emaciated, with an enormous testicle of the hydrocele type and a secondary mass of glands in his abdomen, so large that as he lay upon the examination table this mass protruded visibly.

He was treated by radium pack and one week later, when I removed his testicle, the abdominal tumor was no longer visible, though it was still palpable. Because of the irradiation, the wound healed slowly and when he left the hospital, two weeks after operation, I could feel nothing abnormal in his abdomen. He immediately recovered. I have not seen him since, but he wrote from out of town in 1922 that he was entirely

well, and was indirectly reported as apparently well last year.

Dean's report, based upon a study of 63 patients, classified these as, "primary operable; primary inoperable; recurrent operable; recurrent inoperable; and prophylactic." They were all treated by radiation of low voltage to the testicle and high voltage to the abdomen before operation. High voltage irradiation is repeated two months after the first treatment, the testicle having been removed in the interim.

The number of cases grouped by Dean under his various classifications is so small, and the period since the beginning of his work at Memorial Hospital so brief, that the known survivals (26 in number, or 41 per cent of the series) have not been followed long enough to make a very convincing array. Nevertheless 6 of them extend beyond three years and 2 beyond five years. But it so happens that 39 of these cases, or well over half of them, are classed as "recurrent inoperable." These patients were referred after orchidectomy had been performed. They presented themselves with inoperable local recurrences, inoperable metastases, or both. Eight of them (20 per cent) are living without sign of disease six months, fourteen months, seventeen months, twenty-nine months, four years and eight months, four years and nine months, five years and three months, seven years and seven months, respectively, after the first irradiation. Twenty-four patients are known to be dead, and seven have been lost from the record. These patients were treated by repeated irradiation by high voltage to the abdomen and low voltage to the scrotum, when this was necessary. They were not operated upon. The treatment has at least arrested this frightfully malignant disease.

The above summarizes the situation. These patients had been operated upon without irradiation in vain. Then they received irradiation and 20 per cent of them remained well so far as followed, half of these having been followed for more than five years.

COMPARISON OF RESULTS

It is difficult to compare the results of radiotherapy with those of operation because the objects for which the two treatments are used are scarcely comparable. Radiotherapy takes up the treatment where operation leaves off (so indeed do Coley's toxins), while the attempt to extend the field of operation into the abdomen shows inadequate results which are precisely what one would expect from so extensive an operation performed for so malignant a growth.

REFERENCES

1. Tanner, Chester O. Tumors of the testicle. *Surg., Gynec. & Obst.*, 1922, xxxv, 565–572.
2. Hanfield-Jones, R. M. Treatment of malignant disease of the testicle. *Lancet, Lond.*, 1924, ii, 850–852.
3. Hinman, Frank, Gibson, T. E., and Kutzmann, A. A. The radical operation for teratoma testis. *Surg., Gynec. & Obst.*, 1923, xxxvii, 429–451.
4. Coley, W. B. End-results in malignant diseases of the testis. *Ann. Surg.*, 1923, lxxviii, 370–386.

ABSTRACT OF DISCUSSION ON PAPERS OF DR. DEAN AND DR. KEYES

Dr. Benjamin S. Barringer, New York City. Aside from new discoveries in which the cause of the disease is involved, the control of any surgical condition apparently offers to the surgeon four different ideas:

First, he may do an operation fifty times and at the end of the fiftieth time his speed may have so increased his skill that he may have saved fifteen minutes or half an hour on that particular operation, and so save the patient that much shock, and his mortality will have been reduced. I think that is the least of what we call surgical progress.

Second, he will have found that where he did a very major operation he will be able to do a less major operation with less mortality.

Third, he may have found by considering the various possibilities known, that there are many ways of doing the same thing, and that he can change the major operation into a minor operation.

Fourth, he may have found that he can do away with the operation entirely.

I have reviewed what we have done in carcinoma of the penis and teratoma of the testicle. Eleven years ago carcinoma of the penis meant amputation and dissection of the glands, with some mortality, usually from infection of the large wound at the time of operation. I think in the last few years we have done no complete dissection of the inguinal glands and we have cut down our mortality.

We have found that when the carcinoma has not penetrated Buck's fascia we do not need the operation, and an application of radium will control the disease. We have found in some cases that a simple circumcision will control it. In the cases where radium will not control the disease, in which the tumor has penetrated Buck's fascia and the head of the penis, instead of doing a radical amputation we have made our incision two centimeters beyond the growth, and at the time of operation while an assistant is taking care of the stump, the operator is dissecting the part he has amputated to be sure that he has gone well beyond the carcinoma. We have reduced the mortality of the operation a great deal and in so doing I think have added to the time the patient will live.

I think Dr. Keyes' paper demonstrates that the rather large surgical operation is not all that could be desired. To my mind it is an impossible thing. I have done it, but the point is that we cannot get all the lymphatic glands and the lymphatic tissue out. I think our results have shown that we have been able by irradiation of the abdomen to do away with the operation. All the operation we do in any of these cases is done under novocain infiltration anesthesia, taking the testicle out a certain time after radiation therapy has been completed, generally six weeks to two months after the maximum effect has been attained. The only reason we have operated upon them at all is because we think some carcinoma cells may be growing in the testicle and we might as well eradicate the focus. We have found living malignant cells in the testicle removed six months after irradiation.

One word about the tremendous effect of radium on teratoma of the testis. I recently had a patient who I believed had a teratoma of the testis. Dr. Keyes concurred in this. We sent the patient to the hospital for radiation treatment and about six weeks later took the testicle out and Dr. Ewing could find no evidence of tumor. Gumma had been excluded. I would think we were mistaken in the diagnosis had we not had two similar cases.

Dr. Laurence R. Taussig, San Francisco, Calif. In the early days we treated a number of advanced cases of carcinoma of the penis and found we caused the patient a great deal of pain and did not check the disease to any great extent, so we gave up irradiation and turned them over to the surgeon for palliative operation. We also turned over the early cases, which we do not often get.

I think Dr. Dean's large series will re-awaken our interest in the radium treatment of carcinoma of the penis and will lead us to try his technique.

Dr. George E. Pfahler, Philadelphia. In epithelioma of the penis we have had some good results by removal of the affected part, after preliminary irradiation, by means of electrocoagulation. It certainly takes longer than does operation to complete the treatment, but the remarkable thing is that practically none of these patients have any reaction. They feel like getting up and going about the next day. Just how to explain it I do not know for they have considerable necrosis and sloughing, which is the disagreeable aspect of electrocoagulation. I feel, as does Dr. Keyes, that we make our results more assured if we remove the affected part after we have irradiated.

I have never treated the primary growth in teratoma of the testicle, but on several occasions have treated the metastases in the abdomen. In one instance the man had a mestastasis in his abdomen as large as his head. He was treated in 1918 and the tumor entirely disappeared. I saw him this spring and he is entirely well. Another patient with an extensive mass in the abdomen, secondary to teratoma of the testicle was treated ten years ago and is still well. Another treated five years ago is still well. I believe that in the metastatic cases, provided the disease is still in the abdomen, one is justified in using roentgen irradiation.

I would urge that every patient when he first comes have an examination of the chest. These patients often have metastatic nodules in the chest when we have no reason to suspect them.

It seems to me that if one can get metastatic masses in the abdomen, where they are difficult to irradiate, to remain well, that one could irradiate the tumor while it is still primary in the testicle.

Dr. Dean (closing). The situation in respect to teratoma of the testicle is unique. Surgery has little to offer and as these tumors are composed of embryonal tissue, the effects of radiation are very striking. Dr. Pfahler has spoken of the remarkable effects in the abdomen and we have had two cases with chest metastases which have disappeared following radiation. The patients have been well for over a year. We now treat the abdomen, the chest and the intervening spine, and the connection between the upper vertebral lymph nodes between the abdomen and the lung, is also irradiated. We give the 60 minute exposure with the high voltage roentgen ray, instead of the 80, which seems sufficient to cause death of the embryonal tissue, and we can repeat this in a shorter time because the overlying tissues have not been affected. A patient came in last month with a primary teratoma and large metastases in the

chest and abdomen. He was irradiated, six different portals of entry being used. The primary tumor shrank to the original size of the testicle and the metastases in the abdomen and chest both disappeared.

DR. BARRINGER. I would like to ask Dr. Pfahler whether he amputates with electrocoagulation or just removes the area of the growth. I imagine that he might use a cautery knife and amputate as we do in surgery.

DR. PFAHLER. I have amputated back to the root of the penis, cooking through and then cutting off with the ordinary scissors. The results are more satisfactory than by any other method I have seen.

DR. BARRINGER (closing in absence of Dr. Keyes). As to the effect upon the other testicle, in the light of Dr. Bagg's work we know there must be some effect. One patient who was operated upon three years ago has reported that his wife is eight months' pregnant. I am interested for two reasons: first, because she is pregnant and, second, the effect it may have upon the child in the way of animal experiments reported by Dr. Bagg in the rats which had been irradiated.

COMPLETE INSULATION VERSUS GROUNDING AS PROTECTION AGAINST HIGH TENSION ELECTRIC SHOCKS*

BY WILLIAM FRANCIS HEMLER, M.D.

Georgetown University

WASHINGTON, D. C.

THE number of people who have been killed or seriously shocked and burned by high tension currents in roentgen-ray practice, justifies a serious consideration of the causes of such accidents and of available means of protection. There are few roentgenologists or technicians who have not either been personally sparked or had patients more or less seriously shocked from high tension lines. Accidents of this kind have occurred during the past year and at least one of them resulted fatally; so it is evident that in actual practice the problem has not been solved.

It is not our purpose in this discussion to condemn the proper grounding of such structures as metal conduits, which might otherwise become dangerously charged and possibly injure someone in a distant part of the building. What we wish to demonstrate is that such grounds as well as charged and even uncharged conductors should be insulated to prevent persons from approaching within sparking distance of them, in the presence of high tension voltages.

The real question we present therefore is, whether people should be grounded or completely insulated to best protect them from electrical dangers.

Our investigation was started after one of us had been shocked between a high tension wire and a concrete floor in one of the government hospitals. Before ordering any changes in the plant, we were expected to show an effective means to eliminate or lessen the danger.

A preliminary visit was made to the principal hospitals in three large eastern cities. Concrete floors and numerous other exposed grounds were found in the roentgen-ray rooms of every one of them.

By experiments which we reported in a previous paper we showed that animals which were standing on concrete or were otherwise grounded, were shocked and burned just as severely by contact with one high tension wire as those connected in short circuit between the two high tension lines. On the other hand, animals which were first insulated from grounds by being placed on a wooden floor, and then likewise connected with one high tension line were not in the least harmed. Thus an ungrounded puppy continued to play in contentment wearing a wire collar electrode

* Read at the Twenty-sixth Annual Meeting, AMERICAN ROENTGEN RAY SOCIETY, Washington, D. C., Sept. 22–25, 1925.

charged with 100,000 volts and all resistance out of the line between dog and transformer.

Assured by the immunity to shock thus exhibited by insulated animals, a number of our workers and several visitors submitted themselves as subjects. Seated on a dry varnished hardwood table which had just been tested and proven to be an efficient insulator, these persons handled with impunity in all sorts of ways, the wire attached to either side of a high tension transformer. Not one of them was shocked or felt the least unpleasant sensation although their bodies were charged as a condenser at 100,000 volts from a 10 kw. transformer and all resistance out of the line.

A milliampere meter manufactured to register 150 milliamperes was connected in series with the animal in these tests. The indicator was thrown all the way across the dial when the animal was grounded, but there was no current registered when the animal was insulated from grounds, and from opposite terminal, although he was still connected with one charged high tension line. When the charged wire was in contact with a metal table, if the table was insulated there was no registration of current, but when the wire approached a grounded table a violent flamelike arcing and meter registration occurred, such as every roentgen-ray worker has often observed.

The year following the publication of our experiments on animals, Professor Shearer fully endorsed the principle of absolute insulation of all persons in roentgen-ray laboratories, and the Committee on Safety at the time recommended that persons be insulated from any grounded metal of apparatus. Shearer said, "There seems to be an idea prevalent that if only grounds enough are provided, all else may be neglected. If however one should touch a high tension circuit, then contact with a grounded floor or support is dangerous."

Shearer enumerated nineteen situations entailing danger from high tension currents and showed that in fourteen of these the danger is due to grounds and can be eliminated by merely doing away with exposed grounds.

In the other five situations one would be shocked between the two high tension lines. He said that grounding never secures as good protection from electrical dangers as does complete insulation. Thus grounds are concerned in two-thirds of all electrical dangers, in roentgen-ray work. Indeed in all of the accidents which have been brought to our notice the subject was invariably shocked between one high tension wire and a ground, and never between the two lines, although of course there is real danger from the latter source.

Roentgenologists have been purposely grounding apparatus to get rid of static and to divert the charges to earth in case of a short circuit of high tension currents to the metal of equipment. It should not be forgotten that the high tension current may arc directly from wire or tube terminal to the patient or operator. Now if a person so charged happens to be in contact with a grounded table, tube stand or other equipment all conditions will be fulfilled for him to receive a dangerous—perhaps fatal—shock. Static sparks are never dangerous and may be eliminated by having patient and roentgenoscopist, for instance, both in close contact with the same table equipment, and the whole insulated from grounds. The charging of metal equipments will do no harm as long as the circuit is not completed through a person to ground or the opposite terminal.

We have prepared a summary of the principal sources of grounds and of high tension charges.

SOURCES OF GROUNDS

(1) Concrete floors or any floor or wall containing inbuilt grounds.

(2) Radiators, steam, water or gas pipes, electric conduits, metal lathing or reinforcement steel, either in the room or in the floors or walls.

(3) All low tension wires or neutral or unattached wires, such as transformer cables crossing the floor, foot switches and their cables, drop switches from dim lights, the neutral or filament side of Coolidge tubes on 110 volt, self rectifying outfits, all low tension switches and terminals, and telephone wires and equipment.

(4) Grounded metal tables, tube stands, roentgenoscopes, control cabinet, Bucky diaphragms equipped with electrical signal devices, dental chairs attached to fountain cuspidors, or any metal equipment standing within sparking distance of concrete or other grounds.

(5) Any ungrounded metal structures and equipment are liable to become accidentally grounded.

SOURCES OF HIGH TENSION CURRENTS

(1) Both sides of the larger roentgen-ray transformers and high tension terminal of portable and dental units.

(2) Low tension supply wires, especially the supply lines to filament transformers, become charged with high tension voltage if the transformer breaks down; or if high tension and low tension wires become crossed.

(3) Any ungrounded apparatus or metal material may accidently become charged with high voltages.

It was this well recognized probability of ungrounded conductors becoming accidentally charged with high tension, which led to the indiscriminate grounding which now constitutes a real menace to life in the use of almost every roentgen-ray machine. Although our demonstration proves conclusively that a person may be charged with high tension without receiving a shock, it would be the height of folly to wilfully expose persons to high tension wires in daily practice.

What is needed is adequate insulation at more than one point, so that if one means of protection accidentally fails, there will be additional insulation in reserve to prevent people from being shocked.

In nearly all present day installations the only protection obtainable is for persons not to touch or approach a live wire. No provision is made to protect them in case they should do so. Therefore we understand the necessity for complete insulation

(1) From high tension wires

(2) From grounds

(3) From all conducting material even if it is not grounded

One of the objects of this paper is to urge manufacturers and their electrical engineers and service men to accept the principle of absolute insulation, or of multiple point insulation protection. With such principles employed it would require a simultaneous breakdown at two or more places to shock a person.

One reason given for grounding is because it is required by fire underwriters. Thus it is that metal apparatus is provided with binding posts for fastening ground wires and is sent out with explicit directions that it be grounded to a water pipe or other inbuilt ground.

These instructions are carried too far. If it is not practical to insulate persons from a piece of metal apparatus, then the apparatus itself should not be grounded but should be insulated carefully both from grounds and from high tension. Electrical engineers will easily work out the details if they once accept the principle of absolute insulation.

We have no idea that the means of protection we propose have been overlooked through ignorance. It was due to an attempt to rectify intolerable structural conditions in the places where roentgen-ray apparatus had to be installed.

In the early days there was no room for the roentgen-ray apparatus in the overcrowded hospital, except perhaps in the basement. Concrete floors were the rule in basements, so concrete floors came to be regarded by hospital authorities as perfectly all right in roentgen-ray room.

For manufacturers to have refused to install equipment because proper quarters were not available, meant that they would miss a sale. Roentgenologists themselves were to blame because they did not investigate for themselves, and trusted the manufacturers too implicitly; or they too recognized the necessity of doing their best under improper conditions. And so the evil grew.

We offer the following remedial suggestions.

(1) Build floors, partitions, etc., in roentgen-ray rooms with paraffin treated wood or other efficient insulating material and allow air space between floor and grounds equal to double the sparking capacity of the machines in use plus the length of the nails used to fasten the

flooring. Have forced heated air ventilation beneath.

(2) Low tension as well as high tension conductors which are inside the rooms should be placed high enough so that no person in a normal working position in the rooms can reach them; and as far as possible have them above a special insulating ceiling, of construction similar to the floors.

(3) Place generating machinery including transformers, control cabinets and all conductors in special rooms or compartments with insulating guards or partitions around the conductors at sufficient distance to permit a walk way between machine and guarding partition. The doors into such a compartment should be provided with automatic switch control so that the entire line supply will be cut off whenever the door is opened. Two voluntary acts of the person who has entered—besides the closing of the door—should be required to again close the circuit.

(4) No conducting material of any description should be permitted in the exposure rooms or control booth, the controls to be operated by long insulating handles or cords leading from the switch room to the booth.

(5) The closing of the roentgen-ray circuit should require two separate voluntary acts as a double check against having the current accidentally turned on.

(6) No pipes, conduits, radiators, wires or conductors of any description should be allowed inside of roentgen-ray rooms but should be on the outside or protected by guards as provided in Paragraph 1.

(7) Indirect method of heating should be used to eliminate pipes and water.

(8) Exposure tables and other apparatus with which persons must come in contact should be of insulating material. Such metal equipment as is now in use and cannot be discarded should be insulated from ground and from charged conductors by guards described in Paragraph 1.

(9) Darkroom tanks, and all gutters to carry away any possible leakage from faucets, pipes or radiators in adjoining rooms, should be low enough to prevent water from flowing under the exposure room floors.

(10) Portable, dental and roentgenoscopic units should have combined oil immersed tube and transformers. Likewise in any other situation where grounds cannot be eliminated, as in cystoscopic rooms, oil immersed tube transformers should be used exclusively. An oil immersed or unit potential tube transformer outfit is now ready for the market, to operate at 30 milliamperes, 5 inch gap capacity. The oil immersed principle would seem to offer the ideal solution to all high tension troubles.

(11) Rooms constructed and arranged as above described should be demanded in all new buildings and new installations, and old plants modified accordingly.

(12) The roentgen-ray department is equal in importance to the operating room or any other part of a hospital and it requires special construction. Inadequate quarters in a basement or elsewhere should not be tolerated.

We have lately been testing the amount of leakage of high tension currents used in roentgen-ray work, through wooden floors, and through brick walls, etc., under various conditions of atmospheric moisture and temperature.

Of course any insulating material becomes non-operative as such, if flooded with water, as after scrubbing, or during cystoscopic examinations or from other cause; but under all ordinary variations of atmospheric conditions, properly treated wood, as even the ordinary varnished wooden table used in our experiments, maintained its insulating properties throughout the year.

We used a sling psychrometer to determine atmospheric vapor content. While the varnished table, well surrounded by air on all sides was always safe, the untreated, old wooden floors of the building showed a slight amount of leakage on humid summer days after a sudden rise of outdoor temperature when the temperature indoors remained comparatively low. On the most unfavorable days this leakage amounted to as much as 8 milliamperes of current at 100,000 volts. That strength of current is not sufficient to cause serious shock but will cause some pain and slight burns.

Thus wooden floors are more likely to be dangerous in the summer when the tem-

perature indoors is lower than the temperature outside. High atmospheric vapor content had no effect on the conductivity of the floors, in months when the building was heated as there was no condensation of moisture on the wood under those conditions. Floors made of properly treated wood and with good circulation of air beneath are safe insulators, at all times.

The wood should be kiln dried at 70°C. and then plunged into hot paraffin or hot linseed oil. Linseed oil expands as it dries and fills the pores of wood.

It should not be inferred that dental and portable units are not dangerous because their advertised capacity is only 10 milliamperes. This limitation is imposed by the working capacity of the tubes. The transformers themselves are capable of delivering high amperage at increased voltage, and when shortcircuited through persons these currents have caused a number of deaths. Right angled dental tubes are more dangerous that straight radiator tubes, because the filament wires are within sparking distance of the patient's head and are capable of grounding high tension charges through the patient.

TEST FOR DANGER

A simple test for danger is a large electrode attached to a reel wire and charged with 100,000 or 300,000 volts. This should be passed systematically over every part of the room including the floor and walls. The occurrence of sparks or milliampere readings indicates a ground or the line of opposite polarity within dangerous proximity.

ABSTRACT OF DISCUSSION

DR. L. T. LEWALD, New York City. Dr. Hemler has minimized the static effect. I have found that it is quite a problem. We had one case in the hospital where the ground was left off because the table had been moved for us into another room and the ground had not been replaced. The patient made a great deal of disturbance on account of the static; refused to pay the hospital bill, and threatened to sue them, saying that the static discharge he had felt was an electrical shock, and so on.

Of course, patients will move during the exposure if they get a static effect, and I would like to ask him again how he would avoid the static, which is certainly a problem.

DR. HEMLER (closing). I mentioned that the patient should touch the bare table with his bare skin. During fluoroscopy when the operator touches the patient, both should be in direct contact with the same piece of unearthed equipment.

When there are several thicknesses or even one thickness of blanket, clothing or other like material between patient's skin and the equipment, the static spark is felt, but there is no static discharge to the patient if he grasps the bare table top with his uncovered hand.

ROENTGEN-RAY STUDY OF BRONCHIECTASIS*

BY J. J. SINGER, M.D., AND E. A. GRAHAM, M.D.

ST. LOUIS, MISSOURI

IN the study of a very large number of roentgen plates of various chest conditions, certain observations and impressions result which help to make diagnoses that cannot be obtained without these studies. For the past five years we have made bronchiectasis a special study. It is the purpose of this paper to describe our observations.

It has been our custom to take roentgen-ray plates in three positions: (1) anteroposterior, (2) posteroanterior, and (3) horizontal anterior or posterior. While stereoscopic plates are valuable in such a study, it was not feasible to take all plates stereoscopically. Much information was obtained by the comparison of plates taken in these positions, such as relative size of shadows, the increased aeration of the lung, and the difference in shadows when patients are examined roentgenologically before and after emptying large pus pockets in their lungs by postural drainage.

FIG. 1. Shows a definite triangular shadow in the right cardio-diaphragmatic area. One might misinterpret this shadow as a cardiac shadow with adhesion, but a history of profuse and foul sputum with persistent cough and the absence of involvement in other parts of the lung aids in making a true interpretation. At operation this shadow was found to represent a bronchiectatic, atelectatic lobe.

All patients are examined in the usual manner, *i.e.*, inspection, palpation, percussion, and auscultation. A roentgenoscopic examination is then made in various positions. The roentgen-ray plates are taken in those positions which seem to bring out the pathological conditions best. It is often noted that a great amount of pathology when present in the lower lobe of the lung is hidden behind the cardiac shadow. Oftentimes the density of the atelectatic lobe is partly seen through the cardiac shadow. Several of our cases have shown rather diffuse shadows in the contralateral lobe more marked than in the more diseased one, but by manipulating the patient in the positions described above, one can easily make a correct diagnosis.

Diagnostic pneumothorax is a procedure which is of considerable aid in establishing a positive diagnosis as to which lung is the more diseased. The method we employ is to use 0.5 per cent novocaine as a local anesthetic in the axillary area of the suspected side. The anesthetic is also injected into the pleura. The location of the puncture of course depends on the physical signs and the roentgen findings. While it is true that many patients are apprehensive, most of ours have taken the treatment without any discomfort. The nervous high-strung patient is given twilight sleep. When the manometer on the pneumothorax apparatus shows that the needle is in the pleural space, between 100 and 200 c.c. of air is introduced. A roentgenoscopic examination is immediately made to see whether the bronchiectatic area is raised out of its position away from the cardiac shadow. (Note the illustrations showing these conditions.) If the patient is improved by this amount of compression, pneumothorax treatments are continued. Many startling cures have resulted from this treatment alone.

* From the Departments of Medicine and Surgery, Washington University School of Medicine, and Barnes Hospital, St. Louis.

FIG. 2. Shadows are outlined with arrows in the right diaphragmatic area. Patient brought up large quantities of sputum and had occasional hemorrhages. For two years unable to lie flat in bed. Pneumothorax done in an attempt to collapse this lung (see Fig. 3).

FIG. 3. The two lower arrows show the bronchiectatic lobe raised out of the diaphragmatic sinus. The two upper arrows point to the partially collapsed lung which is apparently otherwise normal. Pneumothorax kept up for thirteen months with apparent cure. It is now four years and patient is apparently cured.

FIG. 4. Plate showing bilateral bronchiectasis. Patient brought up tremendous quantities of very foul pus and blood. On first impression one could consider right lower lobe the more involved side, but the negative with good light shows a triangular shadow in the left cardio-diaphragmatic area. When the patient was drained on the postural drainage table by inversion, the physical signs gave evidence of cavity with dense walls (see Fig. 5).

FIG. 5. After the introduction of 500 c.c. of air by pneumothorax, the atelectatic area is seen raised out of the sinus. A dense adhesion is seen at the small arrow. The opposite lung shows evidence of denser shadows, but this is probably due to compression by pneumothorax on the diseased side (see Fig. 6).

FIG. 6. This plate shows what happened when the adhesions tore loose following a fit of coughing (spontaneous pneumothorax). Note the dense cardiac shadow more or less merged with atelectatic area. The lowest arrow points to the tip of the bronchiectatic lobe. At operation all of the lung markings seen in Figure 4, on the left side, were found to be in the upper lobe only. (The atelectatic, bronchiectatic lobe was surrounded by the compensatory upper lobe.)

In many cases the bronchiectatic areas show themselves as triangular shaped densities with the apex at about the hilum, from ⅛ inch to several inches wide extending from the hilum to the diaphragm. The density of these shadows varies with the amount of contained secretion and the position presented to the roentgenoscopic screen or roentgen plate.

We have a specially constructed table for postural drainage which we use to note the changes in the lobe after the drainage of the purulent material from the bronchiectatic areas.

In those cases that have been operated upon, these triangular shadows have been found to represent atelectatic, bronchiectatic lower lobes, with the characteristic cyanotic appearance and indurated feeling on palpation. We have been surprised when the chest cavity was opened, to find that the unaffected lobe or lobes had hypertrophied so much as to fill out the chest cavity and surround the collapsed lobe. In the roentgen plate these collapsed lobes manifest themselves as dense shadows in the region of the cardio-diaphragmatic

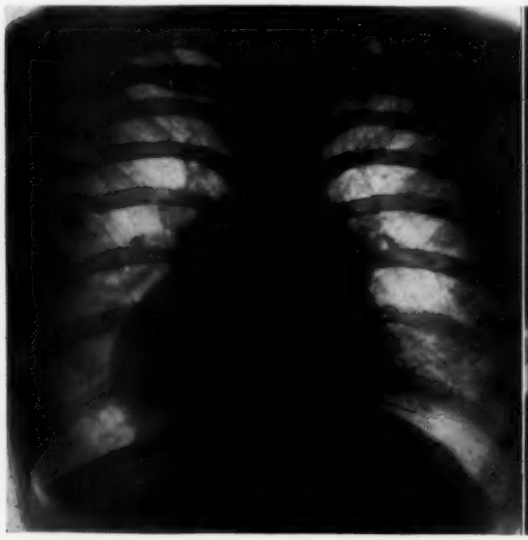


FIG. 7. This shows the first stage of the development of the triangular shadow described in the paper. The plate was taken June 12, 1924, following an attack of influenza. At the time when the plate was taken, it was not recognized as bronchiectasis. Patient brought up only a small amount of sputum.

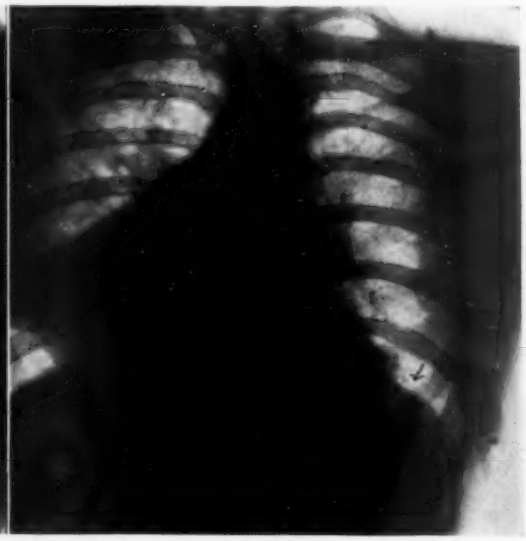


FIG. 8. Same case shown in Figure 7. This plate was taken December 10, 1924. At this time the patient was bringing up large quantities of sputum and had a persistent cough. The triangular shadow is seen from the cardiac shadow merging with the diaphragm. Plate is taken with the patient lying on her left side, plate toward the chest. In this position these dense shadows within dense shadows may be recognized. Patient was operated on, and a bronchiectatic, atelectatic lobe was found at the triangular shadow.

region (see figures). In cases that show diffuse small shadows resembling bronchopneumonic areas in the opposite lung, together with the dense shadows described above, the interpretation has been that this condition is due to a "spill over" from the opposite side. The breath sounds and percussion note are such as one would expect to find in the compensatory lung. Many of our cases improve considerably and the shadows have disappeared when the more diseased lung was treated successfully.

Considerable work has been done in France, South America, and in our own country on the diagnosis of bronchiectasis by other means than those described above, especially the introduction of opaque powders, as bismuth subcarbonate and bismuth in oil. The substances have been introduced through a bronchoscopic tube inserted into the lobe of the lung.

Lipiodol has been used rather extensively in France and in South America. This substance is introduced through a needle inserted into the trachea. Our experience with these methods has been rather limited. Many workers have shown beautiful pictures after the introduction of these substances. We feel that the use of foreign bodies in the lung is not always necessary to make a diagnosis, and it has other drawbacks, such as blocking smaller bronchi. This may become a foreign body and complicate an already serious condition. One such case under our observation had five or six patches of bismuth in the bronchi. Further experimentation with these substances which can be inhaled to the depths of the lung would be of great help in the diagnosis.

FIG. 9. Roentgenogram of patient with a history of cough for four years and bringing up large quantities of sputum. Plate taken with patient lying on the left side, anteroposterior position, following the introduction of 300 c.c. of air into the right pleural cavity. This shadow is represented partly by a triangle, and partly by a curved line. At operation it was found to be a bronchiectatic, atelectatic lobe (see Fig. 10).

FIG. 10. The affected lobe was raised out of its position and sewed to the chest wall. The area of this is outlined by the arrows. Note the peculiar curved lines which we believe represents a collapsed lung without much purulent material. Marked improvement followed this procedure.

CONCLUSIONS

(1) Careful analysis of roentgen-ray plates taken in various positions, together with history and physical signs, gives the best method for making a positive diagnosis of bronchiectasis.

(2) Diagnostic pneumothorax in specially selected cases gives definite information as to the more diseased lung in bilateral bronchiectasis.

(3) Postural drainage should be instituted in bronchiectatic cases after the first plate is taken. Subsequent plates will give information as to the relative size of the bronchiectatic area. Diagnosis of atelectatic, bronchiectatic lobes can be diagnosed before operation.

SECONDARY EVIDENCE OF GALL-BLADDER DISEASE*

BY WEBSTER W. BELDEN, M.D.

Director of Department of Roentgenology, New York Hospital

NEW YORK CITY

AS a preface to this paper we wish it to be distinctly understood that no attempt is made to claim any new discovery in this most absorbing subject which has been covered so completely by Cole of New York, George and Leonard of Boston, Imboden of New York and many others, but if we are able to stimulate the enthusiasm of only a few men and to get them to look more often for these signs, we feel it will be written in a good cause. Cole on May 9, 1913, read a paper, in which he discussed "Gall-Bladder Disease from the Primary and Secondary Evidence" and he stated that the secondary evidence was the more important because it occurred more frequently.

How frequently has it been the experience of all of us that a patient is referred for an examination with pain in the right upper quadrant and clinical symptoms which simulate gastric or duodenal ulcer and at times, gastric carcinoma, and even the roentgen findings simulate these grave pathological lesions but in which congenital or acquired bands of adhesions in the right upper quadrant are the real cause of the signs and symptoms. If we are to avoid erroneous diagnosis we must recognize the existence of these bands, always bearing in mind that these adhesions cause filling defects and that they demand special consideration.

During laparotomies surgeons have recognized these adhesions or veils and have described them at various times. In 1905, Morris referred to them as "cobwebs in the attic" and Harris, in 1914, described them, and this has given rise to the so-called Harris membrane.

Morris believed that these adhesions were of "gall spider" origin and therefore an acquired pathological condition caused by penetration of toxins through the gall-bladder wall and its ducts. He also described congenital veils and should receive due credit for drawing attention to this fact.

Cole, in 1922, in his paper "Veils in the Right Hyochondrium" says, "While it is possible in many cases to make a positive differential diagnosis between cancer, ulcer, gall-bladder adhesions, spasm and this veil or membrane, yet there are cases where these conditions so closely simulate each other that one is justified in making a positive diagnosis of an organic lesion, not a spasm, involving the cap or stomach or duodenum stating that this may be due either to an ulcer, gall-bladder adhesions or a veil, the weight of evidence being in favor of the one which it most closely resembles. In such cases the surgeon should be forewarned and go armed in search of a veil, especially if he does not find an easily recognized ulcer or pathological gall-bladder. An erroneous diagnosis

*Read at the Twenty-sixth Annual Meeting, AMERICAN ROENTGEN RAY SOCIETY, Washington, D. C., Sept. 22–25, 1925.

is thereby turned into a correct one, the pathology detected and the patient relieved of his symptoms."

Eastman's paper on "Chronic Intestinal Infections," is of great interest and has a direct bearing upon deformities of the duodenum which we have been in the habit of classifying as reflex spasm, due either to chronically diseased appendix or gall-bladder disease. He states that these deformities are not spastic in origin but are due to a chronic inflammation in the

FIG. 1. Roentgenogram taken in the prone position showing the "spider leg" or saw toothed projections from the lumen of the duodenal cap as the result of gall-bladder adhesions.

duodenum, cecum, etc., manifested by round cell inflammation of the duodenum proven by biopsy.

It would seem that there is an element of doubt concerning this, since the intestines, especially the duodenum, contain a considerable amount of lymphoid tissue manifested by collections of round cells. Is it not possible that the biopsy may cut through such an area? Then, too, the personal equation of the interpretation of the number of small round cells present as to whether they are normal in number or so very much increased as to indicate chronic inflammation enters into the matter. We are at present working on this and hope within a short time to be able to give some information on the subject.

Therefore, the effort of this paper is to emphasize the fact that we have a definite diagnostic aid which will enable us to reach a much higher percentage of success in discovering pathology of the gall-bladder, if roentgenologists will look more carefully for the evidence. This diagnostic aid is termed secondary or indirect evidence of gall-bladder disease and from the roentgen standpoint is of utmost importance in diagnosing cholecystitis.

FIG. 2. Shows the fixation of the duodenum with the saw toothed irregularities and also fixation of the second portion of the duodenum to the gall-bladder, with visualized gallstones.

It must be admitted that the examination of the gall-bladder for direct roentgen-ray evidence of cholecystitis or cholelithiasis, is at the best not an entirely satisfactory diagnostic procedure, for the reason that many factors enter into the question; the main difficulty is the fact that the gall-bladder is a hollow viscus containing bile and ordinarily does not cast sufficient shadow to be easily demonstrated on a roentgen film or plate. It is well known that the gall-bladder changes in size and shape during the phases of digestion; consequently when it is visualized we have no definite information that pathology is present.

It is a fact, proven by operation and autopsy that the normal gall-bladder is often visualized, notwithstanding the fact that some authorities on the subject claim that a gall-bladder that is visualized on a roentgen negative is pathological.

The question of demonstration of calculi is also of somewhat doubtful value, experience teaching that gallstones are visualized by positive or negative shadows in about 20 per cent of cases.

The roentgen examination of this region should be an easy procedure but it requires exact technique. It is unnecessary to go into the technique of the examination for there is nothing complicated in the making of roentgen-ray exposures. The simplest way is always the best way; therefore; discard anything which seems an unnecessary complication. However, cooperation by the patient to achieve absolute suspension of respiration and quiet during the exposure and also careful preparation of the patient for the examination must be emphasized. The salient points of this preparation being:

1. All drugs should be omitted for at least forty hours before the examination, especially bismuth and barium.

2. The examination should be made on the fasting stomach.

3. A cleansing enema should be given but cathartics are to be avoided as they interfere with the subsequent intestinal motility.

It is very important in gastrointestinal work to study the patients in their usual habits of living. The administration of cathartics definitely interferes with the motor function of the gastrointestinal tract.

Until we discover some easy practical method of visualizing the gall-bladder and gallstones, as we can now demonstrate the gastrointestinal tract by the barium meal we believe that more importance should be placed on the indirect evidence. The use of the Potter-Bucky diaphragm, and advent of double screens and superspeed films have aided materially. We are all hopeful that the method devised by Graham and Cole of visualizing the gall-bladder by the intravenous or oral administration of the sodium salt of tetraiodophenolphthalein which has replaced the calcium salt of tetrabromphenolphthalein, previously administered intravenously may prove to be of tremendous advantage in visualizing the gall-bladder.

FIG. 3. Demonstrates the picking up and displacement to the right of the second portion of the duodenum with irregularities in outline and narrowing due to adhesions and fixation to the gall-bladder.

FIG. 4. Again demonstrates the displacement and fixation of the second portion of the duodenum and the sharp angulation between the first and second portions which may cause functional gastric retention. Shows one gallstone.

Dr. Stewart has done considerable work with the administration of the salt of tetraiodophenolphthalein by the duodenal tube. At present it is only in the experimental stage for the majority of physicians and roentgenologists. However, it seems that we are on the threshold of a method which will become as easy of application and as accurate in its results as the present method of the gastrointestinal examination by the barium meal.

FIG. 5. Demonstrates the displacement and narrowing of the second portion of the duodenum by adhesions. The second portion seems to outline the fundus of the gall-bladder and at operation was proven to be adherent to the gall-bladder.

We are using the tetraiodophenolphthalein salt orally almost exclusively and find that the visualization of the gall-bladder is quite as satisfactory as by the intravenous method using either the iodine or bromine salt.

The great advantage in this method is the fact that the patient does not have to be hospitalized. Some of the patients, however, have quite severe reactions, manifested by marked purgation, considerable nausea and in some cases even vomiting. We are of the opinion that this is due to the fact that too much of the iodine salt is given, and we have reduced the dose by about one-quarter and find that the reaction is very much less severe. Some of the men have reduced it even more than this but so far we have not been successful in getting good visualization of the gall-bladder by a smaller dose.

It does not seem proper at this time to go into the normal and abnormal findings of the gall-bladder when this test is applied.

The secondary evidence of gall-bladder disease is attained by a study of the various hollow viscera surrounding the gall-bladder, that is, the stomach, duodenum, and colon. Of course, this requires a barium meal to visualize these organs.

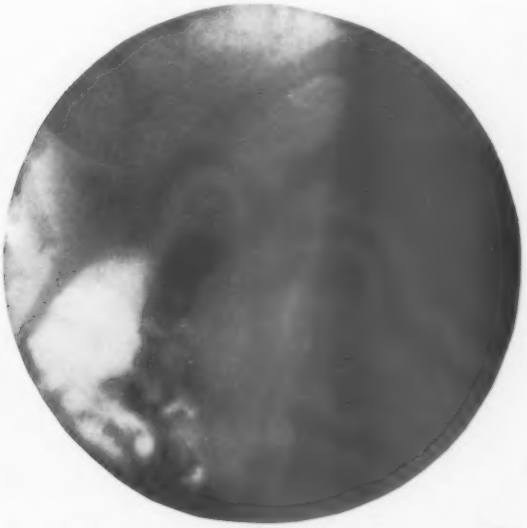


FIG. 6. Tetraiodophenolphthalein visualization of the gall-bladder—oral method. Shows fixation of hepatic flexure as secondary evidence of gall-bladder disease.

George and Leonard of Boston, in their book, "Pathological Gall Bladders"[1] state, "The most common type of indirect evidence, is deformity of the stomach and duodenum, due to pressure from a distended gall-bladder." However, our experience has been that the most common types of secondary or indirect evidence are the irregularities and deformities due to adhesions, resulting in fixation of the first and second portions of the duodenum, rather than the deformity due to pressure. When the pressure deformities are present they are of more diagnostic importance, because experience teaches that this

[1] George, A. W., and Leonard, R. D. The Pathological Gall-bladder, Roentgenologically Considered, N. Y. 1922.

deformity is never produced by a normal gall-bladder. This fact is easily explained by the theory that the tension of the barium filled stomach and duodenum is greater than the tension in the normal gall-bladder, which makes the gall-bladder more easily compressible than the stomach or duodenum. Conditions, however, are reversed when we encounter a thickened gall-bladder distended by bile or stones, or both, which increases its tension and the pressure deformities of the stomach and duodenum result, the "half shadow of George." The deformities which constitute this indirect or secondary evidence of gall-bladder disease, may be classified in two groups, according to their frequency of occurrence.

FIG. 7. Demonstrates the displacement of the second portion of the duodenum and its fixation by one band of adhesions from the gall-bladder. There is also the filling defect caused by pressure from the distended gall-bladder noticeable in the cap. This was the exact location of the duodenum at operation.

FIG. 8. Demonstrates the flattening of the duodenal cap which makes it somewhat rectangular in shape due to pressure from a centrally placed, distended gall-bladder.

A. SECONDARY CHANGES DUE TO ADHESIONS

1. The organ most frequently affected by adhesions resulting from inflammation of the gall-bladder is the first portion or cap of the duodenum. The deformities produced by adhesions group themselves into definite types. The most common deformity being spider leg or saw toothed appearing irregularities in outline of the first portion or cap of the duodenum, at its apex and on its greater curvature side. These deformities give the impression of projection from, rather than encroachment upon the lumen of the duodenum.

The next most valuable finding which can be obtained both by the roentgenoscopic and roentgenographic examinations is fixation of the first and second portions of the duodenum and tenderness to palpation, during roentgenoscopy. In the differentiation of these deformities from those caused by ulcer we find that adhesions give the greatest deformities at the time the stomach is full rather than when it is partially empty. Generally the reverse is the case with duodenal ulcer, and the most characteristic deformity becomes more defined up to a certain point in the emptying of the stomach, while the deformities and defects from the gall-bladder adhesions gradually disappear as the stomach empties and relaxes.

The next type of deformity from adhesions involving the first portion of the

duodenum is the complete obliteration of the normal outline, the lumen becoming tubular as though compressed by a band of adhesions. Lastly, is the filling defect, which is a combination of the ulcer or of adhesions or both. It is very difficult and at times practically impossible to differentiate even by surgery, whether this deformity is primarily due to ulcer or adhesions. Surgery has not proved infallible. We believe that it is absolutely impossible for the surgeon to state that a gall-bladder is normal simply by its appearance and by palpating it.

FIG. 9. Demonstrates the crescent-shaped filling defect of the apex of the duodenum from a distended gall-bladder, the "half shadow of George," and also demonstrates the diverticulum of the duodenum at the entrance of duct of Wirsung.

2. The second portion or the descending limb of the duodenum is the next most frequently involved. This is contrary to one's expectations as it lies retroperitoneally. The most comon deformity is a picking up, displacement to the right, narrowing and fixation. This displacement to the right frequently produces an appearance on the film as though the fundus of the gall-bladder were outlined by the descending limb of the duodenum. One also gets the impression that the duodenum is plastered to some structure beneath the liver. The fixation of the second portion taken in conjunction with the adhesions about the first portion of the duodenum frequently results in a sharp angulation, or kinking between the first and second portions of the duodenum. This is best demonstrated in the oblique position. Gastric retention is not a common finding and when present is apt to be functional rather than organic. If there is gastric retention it depends upon the amount of mechanical obstruction caused by the periduodenal adhesions, the degree of resulting angulation between the first and second portions and the ability of the stomach muscles to compensate for this mechanical interference to the passage of the meal through the duodenum. The

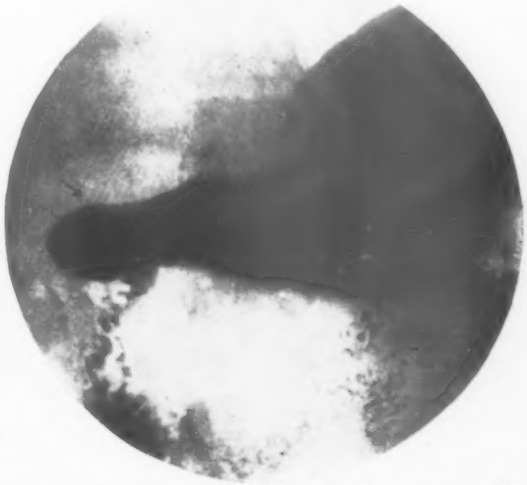


FIG. 10. Roentgenogram taken in the prone position demonstrating the filling defect in the antrum of the stomach which is caused by pressure from a distended gall-bladder.

next most common deformity is the occasional finding of a small narrowing at one point of the descending limb. This type of deformity is usually due to one single band of adhesions.

3. Perhaps the most important finding and one which when present is almost pathognomonic of gall-bladder disease, is the fixation of the hepatic flexure. This consists of a catching up and pulling out of a small portion of the wall of the colon at this point. The resulting deformity has the appearance of a sacculation which usually contains a small bubble of gas above the barium filled colon. This, of course, is due to adhesions from the gall-bladder.

Here again by palpation under the roentgenoscope the fixation can be demonstrated. One must bear in mind that there may be other sources of adhesions in this region; namely, a long retrocecal appendix, tuberculous peritonitis or omental adhesions from other causes, and congenital bands.

Another very characteristic finding occurs in the right proximal portion of the transverse colon. This again consists of picking up and fixing at a short distance from the hepatic flexure. This produces a more or less sharp angulation of the transverse colon, spoken of by George as "pseudohepatic flexure."

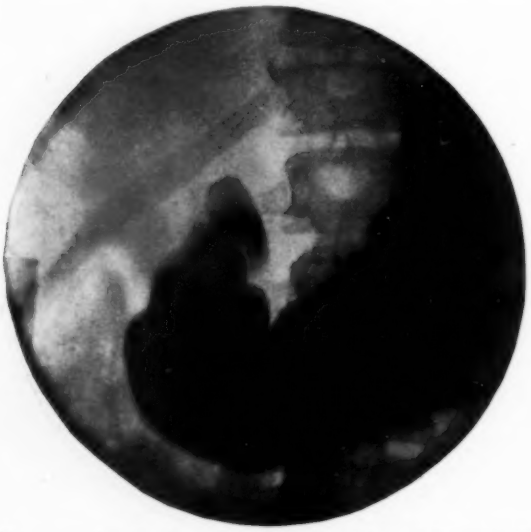


FIG. 11. Again demonstrates the filling defect "half shadow of George," seen in the antrum of the stomach from pressure from the distended gall-bladder. This was situated on the greater curvature side. At operation the antrum of the stomach was found to be densely adherent to the fundus of the gall-bladder. The gall-bladder contained many small stones but these were not visualized by the roentgen ray.

B. DEFORMITIES DUE TO PRESSURE

1. The next most common type of indirect evidence in our experience is the deformity of the stomach and duodenum due to pressure from a distended gall-bladder. This deformity has a charcteristic appearance and is in the nature of an indentation of the viscus. The indentation is apparently produced by some round smooth object, and there are usually no irregularities in the outline of the deformed viscus, the deformity being in the form of a concave curve. The arc of the curve is more or less constant, representing the portion of the gall-bladder that is in contact with the stomach or duodenum. The deformity of the duodenum is usually on its greater curvature or right side. It may occasionally occur on the lesser curvature or left side from a centrally placed gall-bladder. The apex may be flattened by pressure from the gall-bladder producing a more or less rectangular shape of the duodenum and in marked cases produces much flattening of the cap. In rare cases the concave curve will appear scalloped due to pressure from stones within the gall-bladder.

The pressure deformities of the stomach usually occur in the antrum, on the greater curvature side and are best seen in the prone position, which forces the antrum into the right upper quadrant, thus causing it to come in contact with the distended gall-bladder. Although an enlarged gall-bladder is almost always the cause of this curved pressure defect, it must be borne in mind that an abnormal contour of the under surface of the liver may produce a somewhat similar defect. Likewise an enlarged and freely movable kidney has at times caused such filling defects. Rare forms of new growth of the cystic type might cause pressure defects similar to an enlarged gall-bladder, particularly those in the head of the pancreas. With the work which is now being done on the visualization of the gall-bladder by tetraiodophenolphthalein or tetrabromphenolphthalein we will be able to state with very much more accuracy whether these half shadows are caused by a distended gall-bladder or by a Riedel lobe and no doubt will find that the gall-bladder is not as often responsible for these half shadows as was thought to be the case.

There are two other findings which are occasionally met with, one is a narrowing of the pylorus and antrum of the stomach, which gives it a tubular appearance, probably due to reflex spasm and the other is the deformity of the antrum of the stomach spoken of by Cole as "tenting." He considers this pathognomonic. It is

as though a stick had been pushed up beneath a tent which causes a pyramidal appearance and destroys the usual relation between the greater curvature side of the antrum and the greater curvature side of the cap. These two should make nearly a straight line. This sign is found only in the erect position.

In concluding, we wish again to emphasize the importance of the findings of these indirect signs of gall-bladder disease, and to state that no gall-bladder examination is complete without a roentgenoscopic examination of the stomach and duodenum and a roentgenographic examination when possible, because the filling defects caused by adhesions and pressure from a distended gall-bladder very markedly increase our percentage of diagnosis of gall-bladder disease.

DEMONSTRATION OF THE BRONCHIAL TREE BY INTRATRACHEAL INJECTIONS OF LIPIODOL*

BY HENRY W. GRADY, M.D.

Major, Medical Corps, U. S. Army

Walter Reed General Hospital

WASHINGTON, D. C.

THE use of lipiodol, a vegetable oil containing 40 per cent by weight of iodine, in the diagnosis and localization of spinal cord tumors was reported by Sicard and Forestier[1] in 1921. The non-irritating properties of the oil stimulated further investigation which soon resulted in utilizing lipiodol for the purpose of demonstrating the bronchial tree.[2]

Forestier and Leroux[3] injected the oil into the trachea with and without the aid of a laryngeal mirror. The former or transglottic method requiring anesthesia of the larynx was more satisfactory. When the supraglottic method of injection was attempted, without employing the laryngeal mirror, most of the oil entered the esophagus. However, Claisse and Serrand[4] claim that it is possible to inject the oil by the supraglottic method without introducing the cannula into the subglottic space, and without the use of the laryngeal mirror and without anesthesia of the larynx.

Sicard and Forestier recommend either the transglottic method or the subglottic method in which the injection is made through the cricothyroid membrane. Aimé, Brodin and Wolf[5] injected the oil through the cricothyroid membrane.

Sergent and Cottenot[6] have employed the method in a large number of cases. The intercricothyroid route was preferred by them because of the difficulty experienced in the transglottic route by one unaccustomed to the use of the laryngeal mirror. They injected 20 to 40 c.c. through a curved needle introduced through the cricothyroid membrane. Two patients showed slight signs of iodism but there were no serious reactions. The lesions which they have demonstrated after the injection of lipiodol include deviations of the trachea and bronchi, modifications of the permeability of a bronchial area, bronchial dilatation, pulmonary cavities, bronchial and pleural fistulae. They mention the difficulty, and at times impossibility of diagnosing bronchiectasis from a routine roentgenologic examination. In such cases the lesions have been clearly demonstrated after the injection of lipiodol. A number of these cases presented no variation from the normal before the injection. In other cases the appearance was not characteristic of any particular lesion. In a few cases the lesions were obscured by the heart shadow or a pleuropulmonary fibrosis.

Armand-Delille and others[7] have used the method extensively in children, inject-

* Published by permission of the Surgeon General, U. S. Army; Read at the Twenty-sixth Annual Meeting, AMERICAN ROENTGEN RAY SOCIETY, Washington, D. C., Sept. 22–25, 1925.

ing the oil through the cricothyroid membrane. They found the method of great value in proving or disproving the existence of bronchiectasis in children who presented suggestive signs of tuberculosis. They discuss the value of the method in the diagnosis of bronchiectasis, interlobar empyema opening into a bronchus, pulmonary abscess and open hydatid cyst. They advise against the injection in cases of frank tuberculosis because of the possible harmful effects of iodine. They report one case in which symptoms suggesting asphyxia occurred, but the pulse remained normal and the child recovered. They mention a case of iodism with edema of the larynx, which was reported by Boidin who suggests a preliminary investi-

FIG. 1. Case 1. Bronchiectasis.

FIG. 2. Case 1. Bronchiectasis. Left side injected twelve days after injection of right.

FIG. 3. Case 11. Bronchiectasis.

FIG. 4. Case 11. Bronchiectasis. Lateral view.

gation to determine if the patient is particularly susceptible to iodine. They believe the method is safe, that it is of great diagnostic value, and they suggest the possibility of a therapeutic effect.

Nicaud and Dollfus[8] report 2 cases which had been diagnosed for many years as tuberculosis. Examination after the injection of lipiodol showed bronchial dilatation.

Danielsson and Manfred[9] state that the method is harmless and that it is of value in the study of the bronchial tree. They used the supraglottic method with the aid of the laryngoscope. After cocainization of the larynx, they injected about 15 c.c. of the oil.

Bezançon, Weil, Azoulay and Bernard[10] report 2 cases in which the predominant symptom was repeated attacks of hemoptysis. Between the attacks there was no expectoration. Examination after the injection of lipiodol revealed bronchial dilatation.

Sicard and Forestier believe that most of the cases of iodism are due, not entirely to intrapulmonary absorption, but more to swallowing of the oil which is expelled from the larger bronchi a short time after the injection. They state that the method constitutes an appreciable advance in the study of the respiratory apparatus, that it is easy to accomplish, and is without risk to the patient.

Lipiodol has been used in a small number of cases for the purpose of demonstrating bronchiectasis and lung abscess. The intercricothyroid route was used in all cases. The injection is made as follows: A small curved trocar and cannula, 1.5 mm. in diameter, and having the shape of a tracheotomy tube, is used. A glass syringe with a rubber and metal connection for attachment to the cannula is provided. Under local anesthesia the trocar is introduced into the trachea through the cricothyroid membrane. A small amount (about 5 c.c.) of 1 per cent novocaine is now injected into the trachea. As soon as the cough subsides the lipiodol, which has been warmed to body temperature, is injected. The injection is made very slowly. The amount varies from 15 to 20 c.c. The position of the patient varies with the part to be injected. The patient is placed in such a position that the oil will flow into the involved area. Elevating the shoulders slightly and turning the patient to one side causes the oil to flow into the dependent portion of the lung. Changing the degree of inclination during the injection aids in filling the bronchi. Roentgenograms are made immediately after the injection.

FIG. 5. Case III. Bronchiectasis.

FIG. 6. Case III. Four months after injection. Note small amount of lipiodol at left base.

The greater part of the lipiodol is eliminated by coughing within a few hours after the injection. The remainder gradually disappears, usually in one to two weeks. In one case a small amount remained in the lung four months after the injection. No immediate or late ill effects of any importance have been observed. One patient had a slight hoarseness which developed the day after the injection and lasted for two days.

FIG. 7. Case IV. Bronchiectasis.

Bronchiectasis is illustrated in Cases I, II, III, and IV (Figs. 1, 2, 3, 4, 5, 6, and 7). A chronic lung abscess in the upper lobe, and emphysema of the lower lobe, is illustrated in Case V (Figs. 8 and 9).

The number of cases in which this method has been employed is not sufficient to warrant a detailed discussion of its value. The possibility of harmful effects, though slight, cannot be dismissed from consideration. In all of the cases studied the diagnosis was established prior to the injection of lipiodol. However, a few points are worthy of consideration. The location and extent of the affected areas in bronchiectasis and chronic lung abscesses can be more accurately determined after the injection of lipiodol. This is a matter of some importance to the thoracic surgeon. Lesions located behind the heart shadow, or covered by densely thickened pleura, cannot be demonstrated in an ordinary roentgenogram. Because of the high content of iodine, lipiodol is very opaque to the roentgen ray, and casts a dense shadow which can be seen even when covered by the heart shadow or densely thickened pleura.

FIG. 8. Case V. Lung abscess, upper lobe.

FIG. 9. Case V. Emphysema of lower lobe.

REFERENCES

1. Sicard, J.-A., and Forestier, J. Méthode radiographique d'exploration de la cavité épidurale par le lipiodol. *Rev. neurol., Par.*, 1921, xxviii, 1264–1266.
2. Sicard, J.-A., and Forestier, J. Méthode générale d'exploration radiologique par l'huile iodée (lipiodol). *Bull. et mém. Soc. méd. d. hôp. de Par.*, 1922, xlvi, 463–469; Méthode d'exploration radiologique par l'huile iodée. *Presse méd.*, 1923, xxxi, 493–496; L'exploration radiologique des cavités broncho-pulmonaires par les injections intra-trachéales d'huile iodée. *J. méd. franç., Par.*, 1924, xiii, 3–9.
3. Forestier, J., and Leroux, L. Contrôle des injections intra-trachéales par l'emploi d'huile iodée et les rayons X. *Paris méd.*, 1922, xliii, 403–407.
4. Claisse, P., and Serrand, J. Efficacité des injections intratrachéales par méthode sus-glottique; contrôle radiologique. *Paris méd.*, 1922, xliii, 533.
5. Aimé, P., Brodin and Wolf. Exploration radiologique du poumon par injection de lipiodol par voie intercricothyroïdienne. *Bull. et mém. Soc. de radiol. mém. de Par.*, 1922, x, 264–267.
6. Sergent, E., and Cottenot, P. Note sur l'étude radiologique de l'arbre trachéo-bronchique au moyen des injections intratrachéales de lipiodol. *Bull. et mém. Soc. méd. d. hôp. de Par.*, 1923, xlvii, 693–696; L'exploration radiologique de l'appareil respiratoire apres injection intratrachéale de lipiodol. *J. de radiol. et d'électrol., Par.*, 1923, vii, 441–448; Nécessité des injections intra-trachéales de lipiodol pour le diagnostic radiologique de la dilatation bronchique. *Bull. Acad. de méd., Par.*, 1924, xci, 93–100.
7. Armand-Delille, P., Darbois, Duhamel and Marty. Le diagnostic radiologique de la dilatation bronchique chez l'enfant au moyen des injections de lipiodol. *Bull. et mém. Soc. méd. d. hôp. de Par.*, 1923, xlvii, 1618–1624.
   Armand-Delille, P., Duhamel, G., and Marty, P. Le diagnostic de la dilatation bronchique chez l'enfant au moyen du lipiodol. *Presse méd., Par.*, 1924, xxxii, 421–425.
   Armand-Delille, P., and Gelston, C. F. The diagnosis of dilatation of the bronchi in children by means of the injection of iodinized oil. *Am. J. Dis. Child.*, 1924, xxviii, 527–548.
   Armand-Delille, P., and Moncrieff, A. The use of lipiodol in the diagnosis of bronchiectasis. *Brit. M. J., Lond.*, 1924, ii, 7–8.
8. Nicaud, P., and Dollfus, M. A. Contribution a l'étude du diagnostic des dilatations des bronches par l'exploration radiologique apres lipiodol. *Presse méd , Par* , 1924, xxxii, 817–818.
9. Danielsson, E., and Manfred, J. Some experiences of bronchography after injections of lipiodol. *Acta radiol.*, 1924, iii, 157–160.
10. Bezançon, F., Weil, M. P., Azoulay, R. and Bernard, E. Forme seche hemoptoique de la dilatation des bronches. *Bull. Acad. de méd., Par.*, 1924, xci, 100–110.

DISCUSSION

Dr. W. F. Manges, Philadelphia. This is a really important phase of pulmonary diagnosis; the differential diagnosis of pulmonary pathology. The use of anything other than lipiodol for these purposes has not been mentioned, and perhaps it is not the right thing to speak of other substances, but there are so many advantages in the use of bismuth subcarbonate dry which seem to me not to be present with lipiodol, that I think we want to consider this subject of bronchial visualization with substances other than lipiodol.

In the first place, lipiodol is an expensive preparation. It is so expensive that in many clinics, free patients are not apt to get the benefit of it. It is a liquid preparation and depends upon gravity for its distribution in the bronchi. It does not lend itself so well to bronchoscopic application as does the dry bismuth subcarbonate. I think that is a decided disadvantage.

If there is a lesion that involves the bronchial tree, that is not readily diagnosed by straight roentgenographic and fluoroscopic study, then I think that that lesion calls for bronchoscopic study. Oftentimes a chronic infection cannot be differentiated from malignancy and the bronchoscopist can make a very positive diagnosis oftentimes by direct bronchoscopy, even obtaining a direct specimen for microscopic study. I don't object so much to the use of the methods of injecting lipiodol as referred to here today, but I do object to the absence of the careful bronchoscopic study of these cases. With the bronchoscope in place, the surgeon picks out a particular bronchial branch. Take the right bronchus, for instance, he wants to see whether the upper or lower lobe or middle lobe bronchi are patulous; he infiltrates bismuth subcarbonate with a definite air pressure process, so that this bismuth is blown in small, fine particles and adheres to the bronchial wall—and you may believe me that it does go into the small branches of the bronchial tubes, but it does not block the lumen of any of them, or if it does, for a short time, it is not considerable or harmful.

You get an outline of a large portion of the bronchial tree without actually plugging any portion of it. I can conceive of there being some embarrassment as the result of filling suddenly any considerable portion of a bronchial tree with a substance other than air. I think that the infiltration of the bismuth gives a more delicate sense of differentiation of the bronchial lumen than does the liquid lipiodol. For instance, we had a case where, with the infiltration of the bismuth, it was perfectly clear that the lumen of the stem bronchus on the right side was not only irregular in outline but very irregular as to the diameter of its lumen. A lesion was present that almost any of you would have come to the conclusion at once indicated an infiltrating process; in other words a growth. A specimen

taken from that bronchial growth showed that it was carcinoma.

I think that the majority of the lesions in the lower lobe, that are of chronic infectious nature, or that are in the nature of bronchiectasis, are the result of aspiration infections. Then there is that group of abscesses, a good portion of which are due to aspiration infections—aspiration of small particles of tonsil tissue or of small blood clots, and so forth from tonsil and other upper air passage operations. We have recently had two cases in which small fragments of teeth were found in the lower lobe, following tonsillectomy. Dr. Jackson's assistant had a case in which the gauze which was used to anesthetize the tonsil was aspirated. Fortunately, that was recognized at the time and it was removed while the patient was there on the operating table prepared for tonsillectomy. Not all past tonsillectomy abscesses are due to aspiration of infected material.

A great many cases of so-called postoperative pneumonia are nothing more than acute massive collapse of the lung, but not recognized because they have not been roentgenographed. Later on you will find that they have bronchiectasis because there has been a certain amount of organization in the lung tissue as a result of acute collapse and more or less infection, and the bronchi have been stretched because of the presence of cicatricial tissue. These lesions should be studied, as I say, not only roentgenographically before anything is injected, but also bronchoscopically, and if many of the cases are to have a bronchial tree mapped out, the best way to do it is by the insufflation of bismuth. Lipiodol has certain very definite advantages; that is, in small, locally dilated terminal bronchi way down to the diaphragm, a number of which were shown on the screen.

Dr. William H. Stewart, New York City. In our bronchoscopic clinic we have not been so fortunate with the insufflation of bismuth as Dr. Manges.

About five years ago Dr. Henry W. Lynah and I read a paper before this Society in which we demonstrated the bronchial tree lung abscesses and bronchiectasis by means of roentgenographic studies after the injection of a 20 per cent suspension of bismuth subcarbonate in sweet oil into the diseased area through the bronchoscope. Unfortunately, Dr. Lynah died and we had to discontinue the work for a while but now Dr. John D. Kernan is again attempting it. In the few cases in which we have used lipiodol we cannot see any advantage over the bismuth subcarbonate and sweet oil mixture.

I agree with Dr. Manges that the proper way of obtaining an outline of these lesions is by injecting the opaque substance through the bronchoscope. We have tried lipiodol by the gravity method and we have succeeded in outlining the bronchial tree but have never felt confident that we were obtaining detail of the site of the lesion.

The bronchoscope must be introduced and very often, as has been brought out; the mouth of the bronchus is so edematous that none of the oil can enter unless you force it in through the bronchoscope. By this method you can outline many cavities of the lung either with lipiodol or bismuth subcarbonate suspended in sweet oil.

Two years ago I visited Stockholm and saw some of the original work done by Professor Jacobeus in which he used lipiodol, but in none of those cases did I feel confident that I could make a diagnosis of the lesion because the entire tree was outlined.

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

Editor: ARTHUR C. CHRISTIE, M.D.

Editorial Board: JAMES T. CASE, M.D. H. K. PANCOAST, M.D. WILLIAM DUANE, PH.D.

Advisory Board for Pathology: JAMES EWING, M.D. EUGENE OPIE, M.D. A. S. WARTHIN, M.D.

Collaborating Editors: The Officers and Committee Members of the Societies of which this JOURNAL is the official organ, whose names appear on this page, are considered collaborating editors of this JOURNAL. *Foreign Collaborators:* A. BÉCLÈRE, M.D., PARIS. GÖSTA FORSSELL, M.D., STOCKHOLM. G. F. HAENISCH, M.D., HAMBURG. ROBERT KNOX, M.D., LONDON. R. LEDOUX-LEBARD, M.D., PARIS.

Publishers: PAUL B. HOEBER, INC., NEW YORK

Issued Monthly. Subscription $10.00 per year, $11.00 in Canada and $12.00 in foreign countries. Advertising rates submitted on application. Editorial office, 1909 Massachusetts Ave., N.W., Washington, D.C. Office of publication, 67-69 East 59th Street, New York

Information of interest to all readers will be found on page i. Lists of officers of The American Roentgen Ray Society and The American Radium Society will be found below.

Officers and Standing Committees

THE AMERICAN ROENTGEN RAY SOCIETY

President: THOMAS A. GROOVER, 1909 Massachusetts Ave., Washington, D. C.; *President-elect:* RUSSELL D. CARMAN, Mayo Clinic, Rochester, Minn.; *First Vice-President:* P. F. BUTLER, Boston, Mass.; *Second Vice-President:* CHARLES RICHARDS, San Jose, Calif.; *Secretary:* CHARLES L. MARTIN, 701 Medical Arts Bldg., Dallas, Texas; *Treasurer:* WILLIAM A. EVANS, 10 Peterboro St., Detroit, Mich.; *Librarian and Historian:* H. W. DACHTLER, 224 Michigan St., Toledo, Ohio.

Executive Council: H. M. IMBODEN, Chairman, 480 Park Ave., New York City, E. H. SKINNER, Kansas City, Mo., WILLIAM DOUGHTY, Cincinnati, O., THOMAS A. GROOVER, Washington, D. C., RUSSELL D. CARMAN, Rochester, Minn., A. C. CHRISTIE, Washington, D. C., CHARLES L. MARTIN, Dallas, Texas, WILLIAM A. EVANS, Detroit, Mich., RALPH LEONARD, Boston, Mass., RAYMOND C. BEELER, Indianapolis, Ind., ROY A. PAYNE, Portland, Oregon.

Committee on Laws and Public Policy: B. R. KIRKLIN, Chairman, Muncie, Ind., FRED M. HODGES, Richmond, Va., WILLIAM E. CHAMBERLAIN, San Francisco, Calif.

Safety Committee: H. K. PANCOAST, Chairman, University Hospital, Philadelphia, Penna., P. M. HICKEY, Ann Arbor, Mich., J. T. MURPHY, Toledo, O., W. D. COOLIDGE, Schenectady, N. Y., WM. DUANE, Boston, Mass., B. H. NICHOLS, Cleveland, O.

Committee on Scientific Exhibit: LAWRENCE REYNOLDS, Chairman, 10 Peterboro St., Detroit, Mich., B. H. NICHOLS, Cleveland, O., M. C. SOSMAN, Boston, Mass.

Publication Committee: H. M. IMBODEN, Chairman, New York City, WILLIAM A. EVANS, Detroit, Mich., E. H. SKINNER, Kansas City, Mo.

Member, National Research Council: P. M. HICKEY, Ann Arbor, Mich.

Member, American Board of Registry of Radiological Technicians: E. S. BLAINE, Chicago, Ill.

Editor: A. C. CHRISTIE, 1909 Massachusetts Ave., N. W., Washington, D. C.

Editorial Board: JAMES T. CASE, H. K. PANCOAST, WM. DUANE.

Advisory Board for Pathology: JAMES EWING, EUGENE OPIE, ALDRED S. WARTHIN.

Publishers: PAUL B. HOEBER, Inc., 67–69 E. 59th St., New York City.

Twenty-seventh Annual Meeting: Book-Cadillac Hotel, Detroit, Michigan, May 18–21, 1926.

THE AMERICAN RADIUM SOCIETY

President: DOUGLAS QUICK, 350 Park Ave., New York City; *President-Elect:* ALBERT SOILAND, Los Angeles; *First Vice-President:* B. F. SCHREINER, Buffalo; *Second Vice-President:* G. W. GRIER, Pittsburgh; *Secretary:* E. C. ERNST, St. Louis; *Treasurer:* S. M. WITHERS, Denver.

Executive Committee: R. E. LOUCKS, Chairman, Detroit, JAMES T. CASE, Battle Creek, Mich., W. S. NEWCOMET, Philadelphia.

Program Committee: HENRY SCHMITZ, Chairman, Chicago, LEDA J. STACY, Rochester, Minn., B. F. SCHREINER, Buffalo, N. Y.

Publication Committee: H. K. PANCOAST, Chairman, Philadelphia, G. FAILLA, New York City, E. C. ERNST, St. Louis.

Standardization Committee: G. FAILLA, Chairman, New York City, WILHELM STENSTROM, Buffalo, N. Y., A. WEATHERWAX, Philadelphia.

Committee on Arrangements: CHARLES L. MARTIN, Dallas, Texas, JOHN W. CATHCART, El Paso, Texas, OSCAR L. NORSWORTHY, Houston, Texas.

EDITORIALS

ANNUAL MEETING AMERICAN ROENTGEN RAY SOCIETY

IT should not be forgotten that the annual meeting this year is set forward to the month of May. Dr. Carman already has plans well under way for the program. The Caldwell Lecture will be given by Dr. T. Wingate Todd, professor of anatomy in Western Reserve University. Everyone who has visited Dr. Todd's department at Western Reserve has been greatly impressed with his extensive use of the roentgen ray in the study and teaching of anatomy. A Caldwell lecture delivered by him will undoubtedly be interesting, and instructive along many new lines.

Dr. C. Thurstan Holland of Liverpool, one of the pioneer British roentgenologists, and lately chairman of the International Congress of Radiology, will be present and will present a paper.

Dr. Lawrence Reynolds, 10 Peterboro St., Detroit, Michigan, is chairman of the committee on scientific exhibit. A special effort is to be made this year to have a large exhibit of real educational value. It is especially urged that members of the Society cooperate with Dr. Reynolds and his committee to make the scientific exhibit this year of real value.

A valuable feature of the meeting this year will be a trip to Ann Arbor where Dr. Hickey is cooperating with Dr. Carman to arrange a clinical program at the University of Michigan.

TRAINING FOR THE PRACTICE OF ROENTGENOLOGY

It must be evident to all who are in touch with the general status of roentgenology in this country that relatively few young men are undergoing training to fit themselves for the practice of this specialty. There is constant demand for well-trained roentgenologists while the available supply consists largely of men who have acquired their little knowledge of roentgenology in a haphazard and sketchy manner and whose general medical training and experience is often quite unsatisfactory.

Roentgenology is so closely related to nearly every branch of medicine and the roentgenologist is now so widely accorded a place as a medical consultant that only a prolonged and thorough training will fit him for the duties required of him.

Professor Holzknecht, who has been one of the foremost teachers of roentgenology since the earliest days writes on this subject in the April, 1925, *Radiologia medica.*[1]

He laments the lack of sufficient instruction in roentgenology in medical schools and the fact that this very important branch of medicine has been developed rather empirically, following practical demands rather than having been based on scientific foundations. This is due to lack of sufficient time being given to its teaching, to practical methods having been developed without a foundation of general principles, to the material being scattered in different institutes and hospitals and not being available for university teaching purposes and to physicians having taken up the specialty who lack a sufficient preliminary medical culture. One of the very important points in developing good roentgenologists is to select students who have a natural capacity for this branch of work. They must have a scientific trend of mind with special knowledge of pathology and biology and especially well-developed visual and acoustic faculties. Since roentgenology is intimately related to all branches of medicine the roentgenologist must have a good general medical training. As Holzknecht puts it he should be one-tenth roentgenologist and nine-tenths physician. He suggests the following courses: (*a*) for beginners: introduction to general roentgenology, thoracic diagnosis, gastro-intestinal diagnosis, exercises in internal

[1] Holzknecht, Guido. Instruction of physicians in roentgen practice. *Radiol. med.*, April, 1925, xii, 217–222.

diagnosis, diagnosis of internal diseases of infancy, roentgenology of bones and joints, pathology of bone in old age, roentgenology of the cranium; (*b*) for those with a preliminary training: diagnosis of diseases of the skeleton in infants, chronic rheumatic affections of bones and joints, diagnosis of the teeth and jaw, diagnosis of affections of the ear, roentgen therapy, therapeutic exercises, courses in sketching and designing, thorough courses in physics and roentgen technique given by physicians, photography and exercises with the camera obscura, fundamental ideas of physics and technique for roentgen nurses.

Much time should be devoted to the study for it is not merely a question of study from books but time is required for visual and acoustic training and for practical work.

Professor Holzknecht invites discussion of his suggestions in order that better plans of instruction in roentgenology may be introduced in different countries.

We have previously invited the readers of the Journal to send suggestions and plans for courses of instruction in roentgenology both for the undergraduate student of medicine and for graduate instruction of those who intend to become roentgenologists.

The time has undoubtedly arrived when this question should be thoroughly studied in all its aspects by a joint committee representing not only the roentgen and radium societies but the College of Physicians and the College of Surgeons and the Section on Radiology of the American Medical Association. Such a committee could cooperate with the recently established "International Association of University Lecturers on Radiology" of which Dozent Haudek of Vienna is secretary[1] for the purpose of disseminating the knowledge of teaching methods throughout the world. The objects of this association of teachers which are stated as follows might well serve as a guide for the study of this entire question:

"(1) The obligatory instruction of medical students in radiology in all teaching centers.

"(2) The formation of a curriculum for students of radiology and medical students.

"(3) Discussion as to the best methods of teaching and demonstrating difficult sections of radiology.

"(4) The compilation of textbooks for students of radiology.

"(5) The design and construction of models for instructional purposes.

"(6) Exchange of duplicates of instructional models.

"(7) Exchange of the scientific contributions by members and their students.

"(8) Occasional congresses for the exchange of views and discussion.

"(9) Reform of the elementary teaching of biology and physics.

"(10) The introduction of a comprehensive and uniform radiological nomenclature."

[1] Am. J. Roentgenol. & Rad. Therapy, August, 1925, xiv, 158.

NOTICE

The Title Page, Index and Table of Contents for Volume XIV will be found at the end of this number where it may be easily removed for binding purposes. Those desiring may write to the publishers for extra copies which will be supplied gladly.

Subscribers to The American Journal of Roentgenology and Radium Therapy *visiting New York City, are invited to make the office of* The Journal *(69 East 59th Street, New York) their headquarters. Mail, packages or bundles may be addressed in our care. Hotel reservations will gladly be made for those advising us in advance; kindly notify us in detail as to requirements and prices. List of operations in New York hospitals on file in our office daily.*

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this column solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES

WE contemplate the publication of a list of roentgen society meetings such as that below, in each issue of the Journal, gradually adding other home and foreign societies as the information reaches us. Secretaries of societies not here listed are requested to send the necessary information to the editor.

AMERICAN ROENTGEN RAY SOCIETY
Secretary, Dr. Charles L. Martin, Dallas, Texas.
Meets annually.

SECTION ON RADIOLOGY, AMERICAN MEDICAL ASSOCIATION
Secretary, Dr. M. J. Hubeny, 25 E. Washington St., Chicago, Ill.
Annual meeting, Dallas, Texas, April 19–23, 1926.

THE RADIOLOGICAL SOCIETY OF NORTH AMERICA
Secretary, Robert J. May, St. Luke's Hospital, Cleveland, Ohio.
Annual meeting, New Orleans, La., December, 1926.

RADIOLOGICAL SECTION, SOUTHERN MEDICAL ASSOCIATION
Secretary, Dr. Sherwood Moore, St. Louis, Mo.
Annual meeting, Atlanta, Georgia, Nov. 15–18, 1926.

THE CANADIAN RADIOLOGICAL SOCIETY
Secretary, Dr. E. C. Brooks, Montreal.
Meets annually.

CENTRAL ILLINOIS RADIOLOGICAL SOCIETY
Secretary, Dr. C. J. McCullough, Decatur, Illinois.
Regular meetings held quarterly.

CHICAGO ROENTGEN SOCIETY
Secretary, Dr. Edward S. Blaine, 5 S. Wabash Ave.
Meets monthly on second Friday from October to May (except during month of December) at Virginia Hotel. Dinner at 6 P.M., scientific session at 8 P.M.

CLEVELAND RADIOLOGICAL SOCIETY
Secretary, Dr. E. P. McNamee.
Meetings are held at 6 o'clock at the University Club, on the fourth Monday evening of each month from September to April, inclusive.

DETROIT ROENTGEN RAY AND RADIUM SOCIETY
Secretary, Dr. Henry L. Ulbrich, 1130 E. Grand Blvd.
Meets monthly on second Friday from October to May, at Wayne County Medical Society Building.

THE NEW ENGLAND ROENTGEN RAY SOCIETY
Secretary, Dr. Charles W. Blackett, 35 Bay State, Rd., Boston, Mass.
Meets monthly on third Friday, Boston Medical Library.

NEW YORK ROENTGEN SOCIETY
Secretary, Dr. Eugene V. Powell, 217 East 42d St.
Meets monthly on second Monday, New York Academy of Medicine.

PACIFIC COAST ROENTGEN RAY SOCIETY
Secretary, Dr. Harold B. Thompson, Seattle, Wash.
Two meetings a year.

ROENTGEN RAY SOCIETY OF CENTRAL PENNSYLVANIA
Secretary, Dr. W. E. Reiley, Clearfield, Penna.
Two meetings a year, April and October.

PHILADELPHIA ROENTGEN RAY SOCIETY
Secretary, Dr. Eugene Pendergrass, University of Pennsylvania, Philadelphia.
Meets monthly on first Thursday evening, Pennsylvania Hospital.

ST. LOUIS ROENTGEN CLUB
Secretary-Treasurer, Dr. L. R. Sante, Metropolitan Building.
Meets first week of each month. Time and place of meetings designated by president.

TEXAS RADIOLOGICAL SOCIETY
Secretary, Dr. Davis Spangler, Dallas, Texas.

RADIOLOGICAL SECTION, AUSTRALASIAN MEDICAL CONGRESS
Secretary, Dr. C. A. Anderson, The Hospital, Dunedin.
Meets at Dunedin, New Zealand, during February, 1927.

BELGIAN SOCIETY OF ROENTGENOLOGY
Secretary, Dr. J. Boine, Avenue des Alliés, 134, Louvain (Belgium)
Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summertime.

BRITISH INSTITUTE OF RADIOLOGY
Secretary, Dr. John Muir, 32 Welbeck St., London, W. 1.
Meets at 32 Welbeck St., but regular dates and times of meeting have not yet been arranged.

THE BRITISH RÖNTGEN SOCIETY
Meets on the first Tuesday of each month from November to June inclusive, at 8.15 P.M., at the British Institute of Radiology, 32 Welbeck St., London; W. 1.

RADIOLOGICAL SECTION, NEW ZEALAND BRITISH MEDICAL ASSOCIATION
Secretary, Dr. P. C. Fenwick, The Hospital, Christchurch.
Meets annually.

ASSOCIATION OF GERMAN ROENTGENOLOGISTS AND RADIOLOGISTS IN CZECHO-SLOVAKIA
Secretary, Dr. Walter Altschul, German University, Prag, 11/52.
Annual Meeting in Prag the last week of October.

DUTCH SOCIETY OF ELECTROLOGY AND ROENTGENOLOGY

Meets in Amsterdam every second month except in the summertime.

SOCIETA ITALIANA RADIOLOGIA MEDICA

Secretary, Professor M. Ponzio, University of Torino, Torino.

ELECTRO-THERAPEUTIC SECTION OF THE ROYAL SOCIETY OF MEDICINE (CONFINED TO MEDICAL MEMBERS)

Meets on the third Friday of each month during the winter at 8.30 P.M. at the Royal Society of Medcine, 1 Wimpole St., London, W. 1.

SCANDINAVIAN ROENTGEN SOCIETIES

The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies meets every second month except in the summertime:

SOCIETY OF MEDICAL RADIOLOGY OF SWEDEN

Meets in Stockholm.

SOCIETY OF MEDICAL RADIOLOGY IN NORWAY

Meets in Oslo.

SOCIETY OF MEDICAL RADIOLOGY IN DENMARK

Meets in Copenhagen.

SOCIETY OF MEDICAL RADIOLOGY IN FINLAND

Meets in Helsingfors.

SECTION ON RADIOLOGY SOUTHERN MEDICAL ASSOCIATION

At the recent meeting of the Southern Medical Association held in Dallas, Texas, November 9 to 12, the following officers were elected by the Section on Radiology; Chairman, Fred M. Hodges, Richmond, Va.; Vice-Chairman, Gibbs Milliken, Houston, Texas; Secretary, Sherwood Moore, St. Louis, Mo.

DEPARTMENT OF TECHNIQUE

Department Editor: DAVID R. BOWEN, M.D., Pennsylvania Hospital, Philadelphia, Pa

In this department will be published from time to time, as material is available, suggestions for improvement in technique.

NEW DEVICES FOR THE IMPLANTATION AND REMOVAL OF RADIUM NEEDLES

BY HENRY WACHTEL, M.D.

Radium Institute

CRACOW, POLAND

THE radium treatment of malignant growths has been practised heretofore by the implantation of screened metal needles containing radium salt. This method of treatment incurs the risk of breaking the silk thread in attempting to remove the needle. A needle thus left in the tissues makes a surgical operation necessary, involving all the difficulties connected with the extraction of foreign bodies. If a thin wire is used instead of a silk thread it is too rigid and there is no certainty that it also may not be broken.

Investigation of the reasons for the breaking of the thread shows that they lie in the position of the needle in the tissues. Supposing (Fig. 1) that the needle implanted in the growth has become involved in the tissues in such a way that its proximal end, instead of engaging in the canal, impinges upon the contiguous tissue. Of course the needle in this position cannot be withdrawn simply by pulling in the direction of the arrow. Consequently it may be extracted only in case of very slight resistance in the surrounding tissues. If the resistance is considerable a forcible pull only contrives to break the thread.

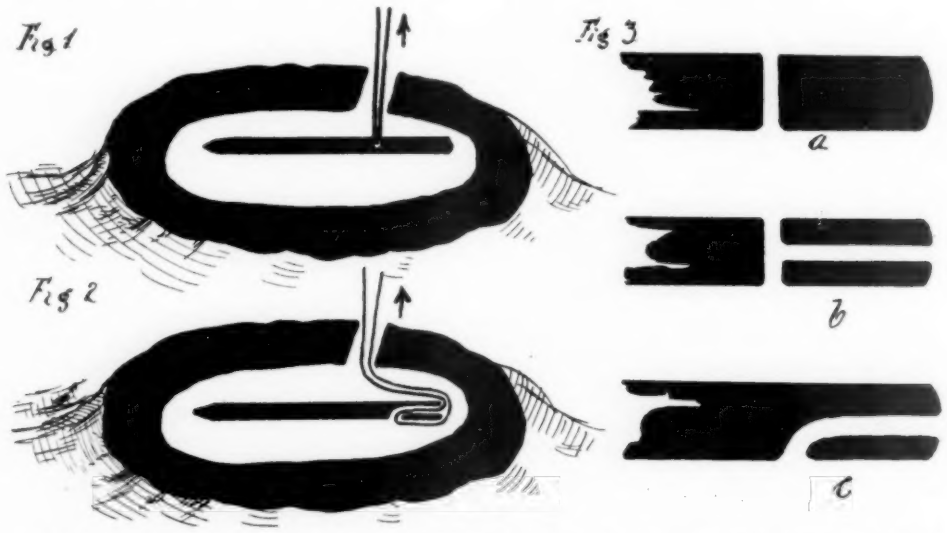


FIG. 3. A schematic profile of the type of the needle showing the direction of the canal for the thread. *a*. Present needle; *b*. The needle constructed according to the suggestion of Professor Rutkowski; *c*. Our latest needle.

This not only shows the error of such a proceeding but indicates what may be done to avoid it. If the pull is not in the direction of the canal it is because of the construction of the eye of the needle.

Suppose the needle caught in the position indicated in Figure 1 had its eye just at the top pulling upon the thread in the direction of the arrow would first of all extract the proximal end from beneath the

tissues, after which it may be very readily withdrawn. Instead, therefore, of pulling with no other result than breaking the thread, the same effort will succeed in extracting the needle. The needle, therefore, must be constructed not only with an eye in the transverse direction but with a groove in the long axis of the needle extending from the proximal end to the transverse eye. Such a needle constructed after a model proposed by Professor Rutkowski of Cracow University may be drawn by two threads as shown in Figure 2. The force acting upon the needle is thus transmitted in another direction than would be the case if the thread passed only through a transverse eye. Further investigation has shown that the best construction of the needle is that represented in Figure 3c. That is, the canal should end in a curve to the lateral wall.

We believe that such a device for extracting radium needles, although seemingly of secondary importance, will practically prove very useful. Of course the above remarks are equally applicable to the screens fitting the radium needles; in order to avoid difficulty in extracting the needle its screen also must have an appropriate shape. When manufacturing radium needles it is of importance that the rims of the holes should be smooth and beveled and not sharp.

I wish also to describe a device used by us when puncturing tissues with radium needles. As is shown in Figure 4, this instrument is composed of a fluted surface like a thimble, fixed on a metal rod, on which is placed a flat button to facilitate the pressure of the fingers when introducing

Fig. 4. Radium puncturing thimble.

the needle. This rod may be bent in different ways depending upon the situation in which it is to be used. It is fixed on the metal needle either definitively or by means of a screw. This last method would be most practical for there could be a set of thimbles of different sizes and forms, each of which could be screwed to the same needle. We find this thimble very useful for it greatly facilitates the puncturing of hard tissues, which is often very difficult.

A MOUNTING CARD FOR FILM REDUCTIONS

BY E. G. C. WILLIAMS, M.D.

DANVILLE, ILLINOIS

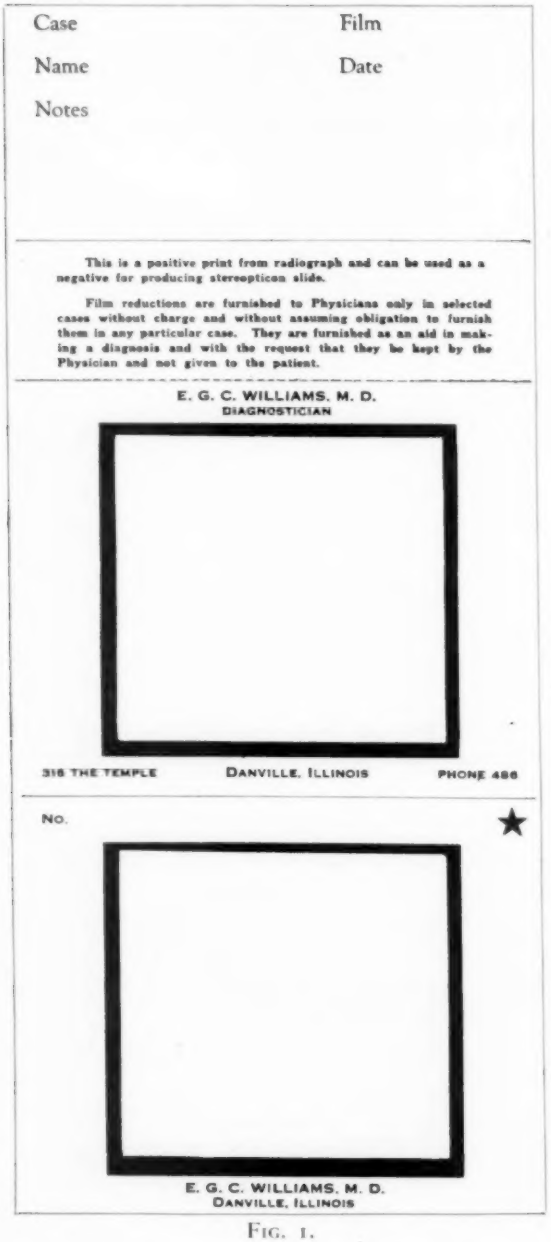

Case
Film
Name
Date
Notes
This is a positive print from radiograph and can be used as a negative for producing stereopticon slide.
Film reductions are furnished to Physicians only in selected cases without charge and without assuming obligation to furnish them in any particular case. They are furnished as an aid in making a diagnosis and with the request that they be kept by the Physician and not given to the patient.
E. G. C. WILLIAMS, M. D.
DIAGNOSTICIAN
316 THE TEMPLE
DANVILLE, ILLINOIS
PHONE 486
No.
E. G. C. WILLIAMS, M. D.
DANVILLE, ILLINOIS

FIG. 1.

IT is sometimes desirable to send film reductions to physicians with case reports. Figure 1 illustrates a mounting card for these reductions. The lower third of the mount is folded backward and the film is glued into position between the two openings.

When the upper third is torn off the mount is lantern slide size and can be used as a lantern slide negative or for a lantern slide if protected from excessive heat. The star marks the thumb spot for lantern position. Figure 2 shows a film reduction mounted. The card is made of green index board. The openings are die cut and bend lines are perforated.

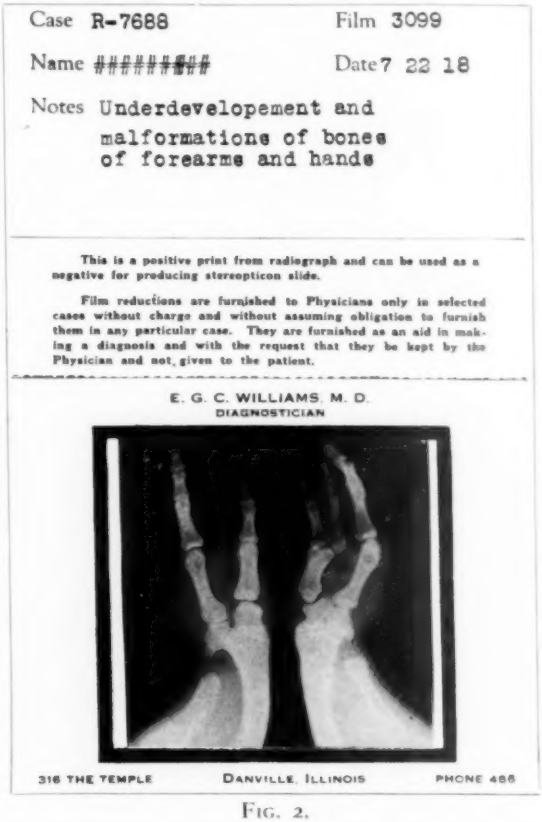

Case R-7688
Film 3099
Name ########
Date 7 22 18
Notes Underdevelopement and malformations of bones of forearms and hands
This is a positive print from radiograph and can be used as a negative for producing stereopticon slide.
Film reductions are furnished to Physicians only in selected cases without charge and without assuming obligation to furnish them in any particular case. They are furnished as an aid in making a diagnosis and with the request that they be kept by the Physician and not given to the patient.
E. G. C. WILLIAMS, M. D.
DIAGNOSTICIAN
316 THE TEMPLE
DANVILLE, ILLINOIS
PHONE 486

FIG. 2.

BOOK REVIEWS

Books Received Are Acknowledged under Heading: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

PHYSIOTHERAPY: THEORY AND CLINICAL APPLICATION. By Harry Eaton Stewart, M.D., Attending Specialist in Physiotherapy, U. S. Marine Hospitals, N. Y.; Director, New Haven School of Physiotherapy. Cloth. Price, $7.50. Pp. 351, with 66 illustrations. New York: Paul B. Hoeber, Inc., 1925.

Physiotherapy, defined as the employment of physical forces of nature in the treatment of injury and disease, may reasonably be considered one of the most direct, potent, and valuable adjuncts in the entire field of therapeutics. It is collateral with materia medica. This field, as is the case with other phases of medical practice, has been suffering from incursions by quackery and unscientific methods of nature healing. With these physiotherapy is of course in no way to be confounded or confused. The author states, "This subject, largely empirical in the past, has, with the development of modern accurate instruments for measurement, made beginnings along the path of exactness of dosage comparable in accuracy with those attained in drug therapy."

The surgeon, the orthopedist, the dermatologist, the industrial surgeon and those called on to treat athletic injuries all have an interest in this domain of therapy. It goes without saying that hospital departments and reconstruction units also have more than a passing interest in it.

This manual by Dr. Stewart, who was formerly in charge of physiotherapy both in the Army and in the United States Public Health Service, confines itself exclusively to the consideration of the theory and clinical application of physical therapeutics. It is assumed that the diagnosis in each instance has been made; and the concern is not with the pathology of the specific condition but with the selection and technique of the particular forms of physiotherapy which may be indicated. Detailed technique, as nearly standardized as possible, is presented.

This volume is about equally divided between theoretical aspects and clinical applications. Chapter headings in the first half are: introduction; galvanism, ionization or electrolysis; sinusoidal, interrupted and wave galvanic currents; faradism; static; high frequency currents; phototherapy; actinotherapy; thermotherapy; massage; exercise; and hydrotherapy. Each of these headings is more or less extensively and competently discussed. In each case the physical agent is defined, and a statement is given of the physics and of the physiological action, together with an exposition of the technique of application, the indications and contraindications, and the therapeutic effects. A knowledge of the indications for the use of such agents must be regarded as an essential of modern medical equipment.

In the part on clinical applications, the following are the chapter headings: diseases and injuries of neuromuscular systems; diseases and injuries of the bones and joints; diseases of cardiovascular system; diseases of gastrointestinal tract; diseases of respiratory sytem; diseases and injuries of the skin; diseases of the genitourinary system; micellaneous conditions; postural defects; foot disabilities. The pathological conditions included in this section are those in which the applications of physical measures have seemed to the author to be of proven value. The aim in presentation is to give the proper blending, alternatives and sequences of all the therapeutic measures applicable to the conditions under discussion.

It should be mentioned that roentgen therapy, a physiotherapeutic agent in the broad sense of the term, does not find a place in this manual. Only occasional references to roentgen therapy are made, as for instance, in diseases of the skin, where it is recognized as an alternative treatment. It is the author's belief that roentgen-ray and radium burns should always be treated with ultraviolet light. In some roentgen-ray burns where skin grafting was at first thought necessary, a preliminary experimental ultraviolet irradiation produced astonishing results and made grafting unnecessary. Over-treatment with ultraviolet light is often given in the treatment of burns, and a word of caution is in order; because many cases have been observed where a delicate single layer of epithelial cells was formed only to be destroyed by too heavy exposures to ultraviolet light, thus delaying the healing indefinitely.

This manual is a good example of the bookmaker's craft. The print is clear and the illustrations are well executed. The occasional typographical error that has slipped by will undoubtedly be eliminated in the next edition.

B. COHEN.

PHYSIKALISCHE UND TECHNISCHE GRUNDLAGEN DER RÖNTGENTHERAPIE. By G. Grossmann. Supplement No. 9 to "Strahlentherapie." Unbound, price, 13.50 M; bound, price, 16.50 M. Pp. 300, with 207 text figures. Berlin and Vienna: Urban and Schwarzenberg, 1925.

This monograph presents a critical survey of the physical and technical elements of roentgen therapy with the object of acquainting the practical roentgenologist with the newer aspects of roentgen physics and technology. It is intended also as a reference work for the inve tiga or in roentgen therapy, and as a guide to the problems and methods of roentgen therapy for the physicist and engineer.

The work is divided into a physical and a technological section. The first contains chapters on the radiation of the roentgen tube; roentgen rays and matter; quantitative aspects of absorption and scattering; therapeutic application of roentgen rays; and on radiophysical methods of measurement. An effort is made to resolve the complex phenomena of absorption and scattering into individual elements that can be visualized and grasped. The main difficulty, according to the author, is the fact that the physicist and the roentgenologist, each has a different concept of the term "absorption."

The theoretical phases of the subject are developed only to the extent of furnishing an adequate basis for the practical worker. Mathematical derivations of formulas are given, where necessary, in the form of footnotes.

The technological section contains chapters on: roentgen tubes for therapy; apparatus for operating roentgen tubes; roentgen installations and protective devices; and measuring methods and instruments in therapeutic practice. Roentgen tubes and apparatus are considered and compared from the standpoint of operation, intrinsic properties and technological advantages rather than as a mere comparison of the products of different manufacturers. Considerable space is devoted to the theory and technique of quantitation of the various necessary factors.

The medical roentgenologist should find very useful this illuminating and critical survey of his technological problems. The presentation is clear; and it is augmented by generally well-chosen and beautifully executed diagrams and text figures.

B. COHEN.

BOOKS RECEIVED

PHYSIKALISCHE UND TECHNISCHE GRUNDLAGEN DER RÖNTGENTHERAPIE. By G. Grossmann. Supplement No. 9 to "Strahlentherapie." Unbound, price, 13.50 M; bound, price, 16.50 M. Pp. 300, with 207 text figures. Berlin and Vienna: Urban and Schwarzenberg, 1925.

TUMORS OF THE COLON AND RECTUM: Their Pathology, Diagnosis and Treatment. By Jerome M. Lynch, M.D., Surgical Director, St. Bartholomew's Hospital, N. Y., and Joseph Felsen, M.D., Attending Pathologist, St. Bartholomew's Hospital. Cloth, Price, $12.00. Pp. 259, with 123 illustrations. New York Paul B. Hoeber, Inc., 1925.

INTERNATIONAL ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

ADAMS, JOHN D., and LEONARD, Ralph D. A developmental anomaly of the patella frequently diagnosed as fracture. *Surg., Gynec. & Obst.*, November, 1925, xli, 601–604.

The patella is a true sesamoid bone, and like sesamoid bones in other parts of the body it is subject to anomalies in its development. It usually develops from one center of ossification and even when arising from two centers of ossification the fully developed patella is usually a single bone. Rarely, it is found to consist of two or more bones. During the past five years 6 cases have come to the attention of the authors in which the patella consisted of two or more separate bones. Four out of the 6 cases had been diagnosed erroneously as fractures.

In the roentgenogram this anomaly presents the following appearance: The outer and upper quadrant of the patella, the portion which is always involved, may consist of one or two separate fragments of bone. The general contour is not distorted. The separate fragment has the same structure as the main portion of the patella. It is entirely surrounded by cortical bone, the midportion resembling normal cancellous bone, the outer and upper surface is curved, the inner surface contiguous with the main portion of the patella is flat, or in the anteroposterior view appears as a straight line. There is a definite space between the adjacent surfaces of this fragment which is about one-sixteenth of an inch wide and uniform throughout all its entire length. This separated fragment may occasionally be divided into two parts, the periphery of both portions consisting of cortical bone, the adjacent margins being straight with a smooth outline. This anomaly is in most cases bilateral.

In a series of 63 cases of fractured patella observed during one year, over 3 per cent were congenital anomalies, erroneously diagnosed as fractures. Three typical cases are cited. The recognition of the possibility of this congenital anomaly is important for economic reasons, if for no other.

ARNOLD, WILHELM. The roentgen diagnosis of liver enchinococcus. *Deutsche med. Wchnschr.*, April 17, 1925, li, 655.

Echinococcus infection of the liver is frequently demonstrable roentgenologically indirectly, as for instance, in cases where the diaphragm becomes raised over the affected area. However, direct roentgenoscopic or roentgenographic demonstration of the infection in the liver occurs only in the rare cases where the cysts have become calcified. A case is described in a laborer, aged fifty-eight years, who presented the symptoms of an alcoholic neuritis. Roentgen examination showed within the liver shadow immediately beneath the diaphragm two elliptical shadows that were movable with deep inspirations. In the first oblique diameter the shadows merged into one. These findings suggested echinococcus infection. The blood picture showing 10 per cent eosinophiles was confirmatory.

BAENSCH. On the technique of duodenal diagnosis. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, April, 1925, xxxiii, 386–388.

The greatest weight should be laid upon roentgenoscopic observations as opposed to roentgenographic. In an organ like the duodenum, direct observation of the functional activity will tell the experienced observer far more than the roentgenogram. Considerable information can be obtained from serial roentgenograms taken according to the technique of Åkerlund. In order to catch the duodenum in its most characteristic phases the author has devised a cassette which operates somewhat on the principle of the reflex camera. A screen permits visualization and at the right moment the film is exposed.

The best "distinctor" for massaging the abdomen during roentgenoscopy is the hand of the investigator and no apparatus can displace it.

BAUERMEISTER, W. The various forms of gastric peristalsis and spasm in the roentgen picture. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, April, 1925, xxxiii, 393–401.

A study and knowledge of Forssell's work is considered absolutely essential for the stomach roentgenologist. It gives an understanding of normal function, and sharpens perception of pathological states. It is not only of theoretical interest but is extremely useful in practice.

A discussion is given of the principal gastric movements that are considered diagnostically important. These include normal peristalsis, rapid peristalsis due to neurosis, peristalsis dissecans, oblique peristalsis occurring in compensating pyloric stenosis, in pyloric stenosis, in ectasia ventriculi, abortive peristalsis and

various forms of retroperistalsis. A brief description is also given of gastric spasm. The original must be consulted for details.

BERG, H. H. Clinical features of cholelithiasis. *Deutsche med. Wchnschr.*, April 17, 1925, li, 651–653.

The value of roentgen rays in diagnosing and studying cholelithiasis is considerably underestimated. Assuming an adequate technique the use of duplitized films, movable Bucky diaphragm, soft radiation with brief exposure, under absolute cessation of breathing, gall-bladder and gallstone shadows can be demonstrated fairly regularly. Calcium encrusted gall-bladder walls due to chronic inflammation produce definite shadows and indicate at once pathology of the gall-bladder. A gall-bladder pathologically enlarged usually presses upon neighboring portions of the gastrointestinal canal producing crescent shaped indentations in the contour of the duodenum, pyloric portion of the stomach or the hepatic flexure. A Riedel lobe can produce similar depressions.

A finding of stones does not *per se* indicate presence or absence of an inflammation nor does it indicate the need for removal of the stones. However, a very high calcium content indicates some inflammatory condition. The roentgen finding has a very special significance, however, in the masked forms of lithiasis which would otherwise go unrecognized but for the roentgenogram. Cholelithiasis ranges from the typical disease with colic as a major symptom to the masked form in which colic is a rare symptom.

Another characteristic of cholelithiasis is the accompanying achylia. Frequently, cases that are clinically diagnosed as nervous vomiting may show themselves under competent roentgen examination to be gall-bladder disease. In some cases the symptoms suggest recurrent endocarditis, and in others chronic gastrointestinal ulceration. Ten cases are briefly cited in which the cholelithiasis was masked by symptoms suggesting other conditions and which were correctly diagnosed with the aid of the roentgenogram.

BIANCHINI, A. Lipiodol in the bronchial tree. *Arch. di radiol.*, May–June, 1925, i, 390–406.

Various techniques have been used in the injection of lipiodol into the bronchial tree for diagnostic purposes. Lipiodol has been chosen for this purpose because, being an oily solution, it does not irritate the bronchial mucous membrane and it even seems to have some therapeutic action.

The author prefers the intercricothyroid site of injection. He uses a trocar to make the puncture and has at hand a syringe containing 5 c.c. of 1 per cent novocain, with a small needle, and a larger needle and syringe for the lipiodol. The whole amount of lipiodol injected runs from 5 to 30 c.c. The patient may be turned on his side, or his head elevated or lowered, depending on the part of the bronchial tree to be examined.

The method is useful in demonstrating deviations of the trachea and bronchi, impermeability of any special field, stenosis of the bronchi and particularly dilatation of the bronchi. In general, in dilatation of the bronchi ordinary roentgenography shows only a more or less diffuse opacity. Lipiodol brings out the condition much more clearly and shows the site of the lesion and the degree of dilatation. Cavities, pulmonary gangrene, pulmonary abscess and fistula may also be diagnosed by the lipiodol method. Two cases are described with 4 roentgengrams in which a probable diagnosis of cavity was made clinically. The question was definitely settled by lipiodol examination, the diagnosis of cavity being confirmed in one case, while in the other the supposed cavity was proved to be an area of consolidation.

BRAASCH, WILLIAM F. Urography (Editorial). *Surg., Gynec. & Obst.*, July, 1925, xli, 114–115.

The term "urography" is used to indicate the roentgen-ray examination of the various divisions of the urinary tract which have been rendered opaque by various mediums. Although the method was first successfully brought out by Voelker and von Lichtenberg in 1906, it is only within the past ten years that its clinical value has been recognized and its use become general. As to the choice of a medium, the fact that sodium iodide solution is isotonic to the tissues in lesser concentration than sodium bromide and is consequently less irritating when retained in the renal pelvis, makes the former preferable. For cystography suspensions of iodide in an oil base and silver iodine emulsions have proved satisfactory. Air inflation is not always satisfactory.

It should be emphasized that urography should not be a routine procedure. There are definite contraindications to its use such as age or great emaciation of the patient; (2) advanced bilateral renal disease, and (3) apparent lack of benefit from surgical treatment. Urography should not be employed merely to corroborate a diagnosis which can be readily made without its use, such as evident hydronephrosis, renal stone or renal tumor. It should be recognized moreover that urography is not without some danger to the patient.

BURRELL, L. S. T., and MELVILLE, STANLEY. The value of lipiodol in the diagnosis of bronchiectasis. *Lancet, Lond.*, Aug. 8, 1925, ii, 278–279.

In many cases there is so much adhesion between the pleural surfaces that artificial pneumothorax cannot be induced, and it has then to be decided whether the better lung is sufficiently healthy to justify so serious an operation as thoracoplasty. A case is cited which illustrates the value of lipiodol in helping to form an opinion as to the state of the better lung. Clinical evidence and the roentgenogram showed there was not enough disease in the unaffected lung to contraindicate a right-sided thoracoplasty. However injection of 20 c.c. of lipiodol into the trachea with the patient lying on the left side disclosed very considerable disease at the base of the left lung, thus contraindicating right-sided thoracoplasty.

CAAN, PAUL. Roentgenology of osteochondritis deformans juvenilis coxae (Calvé-Legg-Perthes) and related diseases (Köhler's disease of the os naviculare and metatarses, Schlatter's disease of the tibia). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, March, 1925, xxxiii, 223–230.

Most of our knowledge as to the nature and pathogenesis of osteochondritis we owe to the roentgenogram. In hardly any other bone disease has the roentgenogram yielded such a measure of scientific information as in osteochondritis, and it still remains a significant aid in diagnosis despite the fact that it shows nothing characteristically pathologic in the early stages of this disease. The first visible changes in osteochondritis are seen roentgenologically in the as yet normally shaped and sharply contoured head cap. These are various sized foci of rarefaction and destruction located subchondrally throughout the whole epiphysis and connected with each other by bridge-like projections. These primary changes do not lie in the joint but within the head of the bone, an important distinction from arthritis deformans. Between these areas of rarefaction are scattered zones of intense density indicating a calcification of the head of the femur running parallel with the destruction. These dense shadows are of special importance for the differential diagnosis of tuberculous coxitis. In the latter case there is a more uniform bone atrophy. The simultaneous destruction and calcification may be so marked in advanced cases as to produce the most grotesque roentgen pictures, showing the bone cap as if broken in two, with many parts sequestrated or fragmented. The individual fragments are of different sizes, hazily bounded; and the portions lying centrally show in contrast to the definitely visible atrophy of the peripheral sections an increased calcium accumulation. The few histological studies made upon the subject give no uniform findings. The findings are partly those of a simple inhibition of growth and disturbance in ossification, and partly a filling of the head of the bone with necrotic foci, tissue remnants and hemorrhagic areas. Other cases show decided pathological changes, such as purulent osteomyelitis and osteitis fibrosa.

It appears that the nature of the process is by no means always identical and this agrees with the variety of anatomical findings, the differences in clinical symptoms and in the roentgenograms. The distinctive characteristics that mark this syndrome are: a process occurring subchondrally in the interior of the epiphysis leading to an undermining of the joint cartilage and a reduction in the integrity of the bone. The numerous deformities occurring are merely secondary effects due to pressure. The disease runs a course of about two to five years and reaches its height in the second or third year. It is not considered fatal and the prognosis as to recovered function and restitution of form varies from case to case.

Köhler's disease of the os naviculare pedis and of the heads of the metatarsals as well as the apophysitis tibiae of Schlatter occur much less frequently than osteochondritis. The roentgenographic changes in the heads of the metatarses show a close resemblance to those in osteochondritis. Clinically, the disease comes on gradually. The actual etiology of the disease is unknown; and the belief that it is due to a compression fracture is considered improbable. The course of the disease is generally very favorable and recovery is usually complete.

In Köhler's disease of the os naviculare the roentgen picture shows considerable change in the size, shape and structure of the bone. The contours are often ragged and irregular. The bone shadow is usually denser than normal but there are usually found irregular small zones of rarefaction. A finer differentiation of structure is usually impossible. Clinical and roentgenologic recovery after about three years is usually perfect.

Schlatter's disease occurs mostly in boys twelve to eighteen years old, and is localized at the insertion of the ligamentum patellae, later tuberosity, of the tibia. The roentgen picture is not so characteristic and is not so easy to describe. The normal calcification of the later tuberosity of the tibia dissolves away irregularly and unevenly. The pathologic picture is hard to differentiate from the normal without clinical symptoms. A thicknening and swelling

of the beak-shaped process with a pronounced lifting of its apex from the anterior surface of the tibia is regarded as pathognomonic of Schlatter's disease. This loosening is probably due to contractions of the quadriceps. In all these conditions conservative methods of treatment are indicated, and only as a last resort should surgery be resorted to.

CARMAN, RUSSELL D. Cholecystography in its application to the diagnosis of cholecystic disease. *Lancet, Lond.*, July 11, 1925, ii, 67–69.

During the last fifteen months more than 1100 patients have been examined at the Mayo Clinic by cholecystography using sodium tetrabromphenolphthalein and sodium tetraiodophenolphthalein administered orally and intravenously. The intravenous administration of the dye offers advantages in superior control of the patient and emphasis of the shadows obtained. Its disadvantages are requirement of punctilious technique and the the hazard of local or systemic reactions. The intravenous use of the pure iodine salt is less provocative of systemic reactions than that of the bromine salt.

The principal advantages of oral administration of the dye are simplicity and freedom from grave reactions. Nausea and purgation occasionally follow the oral administration of either salt, but the iodine compound even when pure, seems to produce these discomforts more often than the brom compound. In the present series the diagnostic results from all the methods of administration have been about equal.

The affirmative diagnoses of gall-bladder disease appear to be well sustained and there were few disappointments in this series of cases. Negative findings with the dye are rather less reliable. Occasionally a definitely diseased gall-bladder will respond normally to the test. The most serious factor in the reliability of a negative diagnosis is the possibility of presence of minute pathological changes in the gall-bladder, probably a residue from more pronounced disease in the past. Such a gall-bladder usually responds normally to cholecystography and may be apparently normal on surgical extirpation. If the history warrants its removal, it seldom fails to reveal at least microscopic evidence of disease.

CARNETT, JOHN BERTON. The calcareous deposits of so-called calcifying subacromial bursitis. *Surg., Gynec. & Obst.*, October, 1925, xli, 404–421.

It is believed that further investigation will demonstrate that a variety of lesions, of which calcareous deposit is one, may give rise to the symptom-complex now usually ascribed to subacromial bursitis.

Clinical histories suggest a division of the patients into two main groups, (1) the acute, and (2) the chronic. The outstanding symptoms in the acute cases were pain and fixation of the shoulder joint. The roentgenogram demonstrated the deposit of lime salts in every acute case. The chronic type of cases either began as such, or were originally of the acute type. Pain was similar to that in the acute cases but varied greatly in intensity in the individual patients. Many chronic cases apparently ran a self-limiting course, and irrespective of the treatment, the patients made a complete recovery in from a few months up to three years. In a very small percentage of the cases the condition persisted much longer (up to twenty years), and there were apt to be long periods of remission of symptoms. In the chronic case also, the calcareous deposit was demonstrated by roentgenographic examination.

In practically all cases the patients who were suffering either from pain or limitation of shoulder motion had a characteristic area of localized tenderness just beneath the acromion process on the anterior or anterolateral aspect of the upper arm, usually over the site of the lesser tuberosity. On roentgenographic examination the calcareous deposits cast a shadow of varying density. The shadow may be thin and hazy or quite as dense as bone. Shadows of both extremes may exist in the same patient. The deposits may be single or multiple, unilateral or bilateral. They vary in size from a pinhead to a silver quarter dollar. They occupy different positions in relation to the head of the humerus in different patients. The roentgenogram may reveal multiple deposits when the shoulder is in external rotation which are concealed in internal rotation. The deposit shadow may overlap the bone shadow and resemble a bony outgrowth, but stereoscopic exploration shows the deposit shadow to be free from the bone. These deposits may undergo spontaneous absorption, but the acute cases may have to be subjected to operation in order to relieve pain.

CARTER, RALPH M. Epicondylitis. *J. Bone & Joint Surg.*, July, 1925, vii, 553–562.

Fourteen cases have been seen in the past few years by the author in which the symptoms were characterized by extreme tenderness on pressure over the lateral epicondyle of the humerus, the pain frequently being referred down the forearm to the hand and fingers. With this pain is associated a weakness of the grip, especially in the forcible grasping of an object. Objective findings are conspicuous by

their absence. To this condition the term "epicondylitis" has been applied. Epicondylitis humeri is variously known as tennis elbow, epicondylalgia, radiohumeral bursitis, sportsman's elbow, musician's palsy, etc. This condition gives rise to disability of greater or less extent and constitutes a definite clinical entity which it is important to recognize.

Epicondylitis is not nearly so uncommon as one may be led to believe and occurs almost exclusively in adults between the ages of thirty and fifty, in women more frequently than men, and seems to follow certain occupational as well as sport activities—particularly those in which the combined movements of supination and flexion of the forearm are employed. No definite pathology is known which will apply to all cases. It is probable that the majority of cases are due to a localized periostitis in the region of the external epicondyle, the result of opposing muscle action frequently repeated. A smaller number of cases are undoubtedly due to inflammation or calcification in the bursa which is sometimes found in this region.

The ultimate prognosis is good, as all cases eventually recover but the course of the disease is characterized by extreme chronicity. The great majority of cases in which there is a complete absence of objective findings are best treated by prolonged rest. Diathermy may be of value. A small number, especially those in which the presence of an inflamed bursa is suspected or proved, should be treated surgically.

CARTER, RALPH M. Fractures of the lower end of the radius. *Surg., Gynec. & Obst.*, September, 1925, xli, 287–297.

In the great majority of cases the characteristic "silver-fork" deformity is present, and the roentgen picture makes known with certainty the condition. Occasionally a case of injury in the region of the lower end of the radius will present itself with localized bone or "pencil" tenderness, considerable swelling which appears at once, and subcutaneous ecchymosis after twenty-four to forty-eight hours. In such a case the roentgen-ray finding is negative and should not be regarded as conclusive, but the case should be treated as a fracture. A cursory examination of the roentgenogram may show apparently no displacement, and there may indeed be none as regards the position of the ends of the two fragments. In such a case particular attention must be paid to the plane of the carpal articulating surface of the radius. If this is not in proper position the result will be a functionally imperfect wrist. Normally this surface is tilted slightly forward; in the case of fracture it is tilted backward as a result of condensation of bone on impaction on the posterior aspect of the fracture.

A thorough knowledge of the anatomy of the parts and the mechanism of the usual fracture is essential to proper treatment. The anatomy is reviewed and various mechanisms described. It is probable that no one mechanism will satisfactorily account for all cases. Successful treatment of these fractures consists in immediate complete reduction, preferably under an anesthetic, and early passive motion and massage. Operative treatment, as a rule, is indicated only in old, badly treated or untreated cases.

COHEN, HENRY, and ROBERTS, R. E. Radiology of the gall-bladder by Graham's method. *Brit. M. J., Lond.*, July 11, 1925, 54–57.

A report is given of the results of examination in 14 cases using sodium tetrabromphenolphthalein injected intravenously. Ten of the cases were subsequently operated on and in only one of these were the surgical findings at variance with the roentgenological deduction. In this case the evidence obtained by the Graham method indicated a pathological condition of the gall-bladder yet at operation no gross evidence of pathology was obtained, the only abnormality being a slender adhesion over the common duct. A striking feature of the cases is the fact that of all 7 cases where pathological condition of the gall-bladder was found at operation only one case gave the slightest evidence of this before application of the Graham method.

COLE, WALLACE H. Primary tumors of the patella. *J. Bone & Joint Surg.*, July, 1925, vii, 637–654.

Tumors of the patella are very rare, only 19 definite cases having been reported in the literature. To these might be added the first two in Schwartz's list of 12 cases, the two specimens mentioned in the discussion of D'Arcy Power's case and Baldwin's unreported case, making a total of twenty-four. The author's case makes the twenty-fifth and is the first benign cyst of the patella recorded. These 25 cases are cited; and they show that all the common tumors of the bone have been found in the patella except myxoma. The course, the treatment and the prognosis of patella tumors are the same as for similar growths in the rest of the bony framework.

The author's case occurred in a woman aged thirty-one. The first roentgenogram showed a rarefied cystic condition of the lower part of the patella and a second roentgenogram showed the condition to be progressing. Apparently

the posterior wall of the tumor had broken down so that the cavity in the patella connected with the knee joint. The clinical diagnosis was not definite but lay between a benign solid or cystic tumor with a remote possibility of tuberculosis or syphilis. Operation was performed and the cavity was thoroughly curetted. Microscopically the tissue removed was a very cellular osteitis fibrosa with some giant cells and many mitotic figures. Bloodgood's report on this tissue states: "The section shows blood clot and the usual picture of osteitis fibrosa, which is very cellular. Also much pigment in the cellular areas and some giant cells. I feel it is not malignant." There was a recurrence in six months which necessitated a second operation. Since then, almost two years, the knee has been as good as ever.

COPHER, GLOVER H. Cholecystrophy. Appearance and disappearance of the shadow. *J. Am M. Ass.*, May 23, 1924, lxxxiv, 1563–1564.

The action of tetraiodophenolphthalien *in vivo* is analogous to that of tetrabromphenolphthalein. Bromine and iodine are excreted in the bile after the intravenous injection of the sodium salts of the above compounds. During the fasting period the bromine or iodine enters the gall-bladder through the cystic duct and is sufficiently concentrated to make the gall-bladder opaque to the roentgen ray for a period of thirty to thirty-five hours. The concentration of these halogens is normally dependent on the retention of the bile in the gall-bladder by the sphincter of the common duct. This is additional evidence of the concentrating activity of the gall-bladder. The maximum concentration of halogen is reached in from sixteen to twenty-four hours after injection. The average concentration of bromine in the gall-bladder when it causes a shadow of maximum density is 0.6 per cent. In bile which has not entered the gall-bladder the average bromine content is only 0.2 per cent.

The greater portion of bromine in the gall-bladder which produces a shadow of that organ after intravenous injection of tetrabromphenolphalthelein leaves the gall-bladder through the cystic duct. It is inferred that a small portion of the bromine may make its exit through the wall of the gall-bladder.

ROENTGEN AND RADIUM THERAPY

CHARLES, ANDREW. Treatment of malignant growth by combined diathermy and deep *x*-ray therapy. *J. Cancer, Dublin*, April, 1924, i, 81–89.

There is no doubt that the results obtained with diathermy and deep roentgen therapy combined may lead to a cure; while diathermy helps to kill the diseased parts by its heating effect, the consecutive deep rays not only help to treat the metastatic conditions, but the primary growth as well, so far as it is beyond the reach of diathermy. In those cases which are either far advanced or where the patient's general condition is too low, life can be prolonged and a certain relief from pain and misery may be guaranteed. The combined treatment can be used not only in operable cases with greater safety and to better advantage than the knife, but it is also useful in cases altogether beyond the scope of the knife. Brief descriptions are given of 5 cases receiving the combined treatment.

FISCHER, HEINRICH. Radioactive ceramic pessaries for benign gynecological conditions. *München. med. Wchnschr.*, Feb. 27, 1925, lxxii, 347–348.

The author has devised the scheme of burning into pessaries of faience ware and porcelain minimal doses (0.0004 to 0.0012 mg.) of radioactive material. The radioactivity of each pessary is determined photographically and the activity is of such an order that the pessary may be applied continuously for eight days without danger. Only where there is considerable secretion do pessaries have to be interchanged. For purposes of disinfection they can be subjected to boiling water without deterioration. Another point in their favor is their low cost.

These radioactive ceramic pessaries have now been in use for three years and the results have been satisfactory. They have been applied in climacteric and pre-climacteric hemorrhages, in meno- and metrorrhagia, metritis, myoma, certain inflammations of the adnexa and erosions of the cervix. A total of 50 cases have been treated and this pessary has successfully served as a harmless hemostatic. The general result was the resumption of the normal menstruation or an oligomenorrhea. This is considered better than the method whereby 20 to 50 mg. of radium are applied in order to produce a definite amenorrhea.

GRATTAN, JAMES FRANCIS. Rhinophyma. *Surg., Gynec. & Obst.*, July, 1925, xli, 99–102.

A report is given of 6 cases cured by radical operation followed by roentgen-ray and acid treatments to relieve the associated hypertrophy of the skin and to reduce the operative scars to a state of invisibility. The roentgen-ray treatment consisted of 2 doses of one-half unit at weekly intervals, including one-quarter unit each time to the entire face to clear up the remains of the general acne. Fifty per cent

trichloracetic acid was applied to the elevated areas at the end of the third week. The scabbing from this application usually required from six to seven days for completion. A pink area remained, after the scab separated itself, for about four to five days. This was replaced by the normal color. Subsequent repetitions of the roentgen-ray and acid application were guided by the necessity of the individual case. The entire time required for the elimination of the irregularities and scars of the operation varied from three to five months. When the patient was willing to continue until a practically ideal condition of the skin of both the nose and the face was obtained, this period was extended.

HALBERSTAEDTER, L. The irradiation of the endocrine glands in cancerous individuals. *Deutsche med. Wchnschr.*, Oct. 2, 1925, li, 1646–1647.

Manfred Fränkel of Berlin has fostered not only in scientific literature but in the daily press the idea that a "stimulative" irradiation of the endocrine glands may be the means of combatting cancer, and further that the disease originates in these structures.

The author presents a vigorous criticism of Fränkel's views. There is no proof that the origination of carcinoma or its development is due to a hypofunction of the endocrines. That elimination of this hypofunction causes recession of the developed cancer is also unproven. Consequently there is no substantial support for the framework of theory that Fränkel has put forth. Even if it be assumed that the above two main points are correct, there is as yet no proof that glandular hypofunction can be eliminated by means of roentgen rays. On the contrary there is reasonably good experimental and clinical evidence that poorly functioning endocrine glands are precisely the ones that should be protected from the harmful action of radiation. Temporary "stimulation" is always followed by injurious after-effects.

HEIMANN, FRITZ. Mild irradiation. *Klin. Wchnschr.*, Sept. 17, 1925, iv, 1815–1818.

The treatment with weak doses of roentgen rays as opposed to intensive irradiation possesses a number of advantages. It is applicable in a wide variety of conditions, and although it is yet too early to pass a final verdict as to its value, it may be stated that the injuries produced are far milder than those due to intensive treatment. A great many experimental researches have been so impressive that in many German clinics there has been in recent years a gradual return from the practice of intense to mild irradiation.

A few examples of the utility of mild irradiation in gynecology are cited in the treatment of amenorrhea or sterility due to ovarian hypofunction. The author uses a Symmetrie apparatus administering 10 per cent of a skin unit dose, through 0.5 mm. Zn directly over the ovary. This dose is divided over two or three sittings. Five cases are briefly cited, 2 of which were successfully treated, one improved and 2 failed.

Another useful field is the mild irradiation of the spleen in the treatment of hemorrhage in young girls. The spleen is located exactly, and 10 to 25 per cent of a skin unit dose is administered in the lateral position; and if no result occurs in a few days the dose is repeated after six to eight days. Three cases are cited in 2 of which the results were successful. The method is extraordinarily simple and convenient, and should be used in the case of children before resorting to other more serious measures.

Irradiation of the hypophysis and thyroid is another field where mild dosage produces remarkable results. The glands receive about 5 to 10 per cent of a skin unit dose. The hypophysis receives the radiation from both temples and the thyroid receives a single central field. The dose may be repeated not before eight days and more than three doses should not be given. A case is described in a woman who had received a roentgen castration dose and was suffering from acute symptoms. Mild irradiation of the hypophysis and thyroid yielded satisfactory results.

KAPLAN, IRA I. Roentgen-ray therapy in pituitary tumor. *J. Am. M. Ass.*, July 25, 1925, lxxxv, 268–269.

A report is given of a case in a man aged thirty-four who gave a definite history of trauma. The roentgenogram showed marked erosion of the sella; and there were no apparent skeletal changes. The patient complained of headaches and partial loss of vision, but had noticed no loss of sexual function and had had no urinary symptoms. The roentgenogram showed the skull of moderate size and thickness, the diploic layer normal, slight convolutional impressions present in the frontal region, and calcification of the pineal body. The sella was large, the anterior clinoid was well formed and not eroded, the posterior clinoid was thin, apparently the result of pressure atrophy, and the floor of the sella was depressed. The neurologic examination agreed with the roentgenologic in the diagnosis of pituitary tumor.

The patient received roentgen-ray treatment consisting of a full erythema dose over each of two temporal and one frontal areas in alternate and divided doses, using 190 kv., 4 ma., 0.5 mm. Cu plus 1 mm. Al, 50 cm. distance; 3 inch diameter fields. A second series of

roentgen treatments was given about six weeks after the last and the patient was very much improved. There was evidently no permanent effect on the optic nerve as there was complete return of vision following reduction of the tumor mass.

KLIENEBERGER, CARL. The use of roentgen rays in internal medicine. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, April, 1925, xxxiii, 408–413.

In view of the paucity of animal data, the absence of physiological limits of dosage, and the impossibility of establishing a physical measure of the biological effects, taking into account also the individual variation in radiosensitivity, the application of radiation therapy in internal medicine is dependent for the present upon personal experience, cautious application and re-adjustments of technique. The statements of dosage in the various diseases mentioned below are those which have been observed to occasion no injury.

Cases of recurring facial erysipelas radiating from the nose, receiving one or two treatments with a half skin unit dose upon the nasal mucosa were generally found to result in more infrequent recidives. Neuralgias, trigeminal and ischial, receiving one-third to one-half skin unit dose in conjunction with other treatment were favorably affected.

The application of roentgen rays and judgment of the effect in tuberculosis vary. The author is not convinced that there is a sure effect of roentgen irradiation in pulmonary tuberculosis. On the other hand, laryngeal tuberculosis seems to be favorably influenced by the radiation. Small doses at large intervals seem to be most effective (one-fourth to one-sixth skin unit dose in two or three month intervals). In bone and joint tuberculosis good results are obtained by roentgen irradiation, according to the depth of the process, with one-third to one-half skin unit dose filtered through zinc, at intervals of 1.5 to 3 months. Equal if not better results are obtained also in glandular tuberculosis before caseation has occurred. Excellent results have also been obtained by the application of one-half skin unit doses, zinc filtered, two to three months apart in urogenital tuberculosis. In peritoneal tuberculosis one-tenth to one-fifteenth of a skin unit dose in distant fields, combined with other procedures, yields apparently favorable results. In the treatment of all tuberculous affections the general condition of the individual plays as important a rôle as the nature of the process.

In goiter accompanied by compression of the trachea, relatively intensive irradiation (repeated doses of one-half skin unit dose from various angles) has given excellent and permanent results. Doses of one-fourth to one-third of a skin unit dose, zinc filtered, at two or four week intervals have been found to cause satisfactory regression of large goiters in young and old women. Careful dosage was also found to yield satisfactory results in Basedow's disease, provided the cardiac symptoms did not demand the more rapid results produced by operation.

The effect on tumors by irradiation is more pronounced the worse the general condition of the patient. Gastric and esophageal tumors are insensitive to roentgen rays and an effect upon lung tumors is also questioned. Combined treatment with radium and roentgen rays seems to be the best method of treatment for rectal carcinomas. The roentgen treatment alone seems to be without effect.

Attempts to treat true pernicious anemia with recommended stimulative doses (one-third of a skin unit dose repeated at intervals) have never resulted, in the author's experience, in the slightest favorable effect. Polycythemia apparently yields to roentgen treatment provided very extensive series of irradiations are given. Not the slightest effect has been observed to result from irradiation of the spleen in cases of true pseudoleucemia, malarial spleen, polycythemia rubra, so-called Banti's disease and cirrhosis of the liver. It is now generally recognized that roentgen irradiation of so-called acute leucemias is useless, and it should be remembered that under long-continued roentgen irradiation chronic myelemia may be transformed into an acute myeloblastic leucemia. It does not appear that roentgen irradiation prolongs life in leucemias even though it produces temporary improvement.

PHILIPS, HERMAN B., and TUNICK, ISIDOR S. Roentgen-ray therapy of thrombo-angiitis obliterans. *J. Am. M. Ass.*, May 16, 1925, lxxxiv, 1469–1472.

A preliminary report is given of the results of roentgen-ray therapy in a series of 50 cases of circulatory disturbances of the extremities, mostly thrombo-angiitis obliterans. The roentgen-ray technique used was maintained throughout the entire series. The doses were essentially stimulating ones, and consisted of ten to fifteen minutes' exposure, alternating at weekly intervals over the mid anterior and posterior aspects of the body from the 10th dorsal to the 5th lumbar vertebrae in lower extremity affections, and over the cervical and upper two dorsal segments in upper extremity disturbances. The rays were produced by 100 kv., 5 ma., through 5 mm. Al, 15-in. distance.

As a result of irradiation the pain accompanying thrombo-angiitis obliterans ceased in about two or three weeks. In some cases the relief was immediate. Since most of the amputations in this disease are necessitated by the excruciating pain, it is obvious at once that the radiation treatment is a distinct step forward, since amputation was necessary in only 2 per cent of the present series of cases, whereas the usual average is 60 to 70 per cent.

There was pronounced improvement in the intermittent claudication within one or two weeks. This disturbing symptom disappeared completely in 50 per cent of the cases after the sixth week, and there was a material relief from this symptom in all. Improvement in the circulatory and trophic disturbances is noticeable in from four to six weeks and there is a distinct change in the color of the extremity. No restoration of absent pulse was noted at any time in any of the cases. Favorable changes in the circulation must be attributed to improvement in the collateral circulation as well as to diminution of the venous obstruction.

Phlebitis shows improvement after the first treatment. Active signs of inflammation disappear with supervening signs of resolution. Ulcerations show a tendency to improve in two or three weeks and disappear within two or three months. About ten ulcers in the present series of cases were healed in from six to eight weeks. When gangrene of the toes or other parts was present the tendency of the part to become dry was noticed early, with early establishment of a line of demarcation.

These observations on radiation therapy extend for only about a year and a half, but whatever the ultimate outcome there seems no doubt that radiation therapy is a valuable form of treatment for this condition. Five of the cases are cited.

PILGER, W. Radium in the treatment of cancer. *J. Cancer, Dublin*, April, 1924, i, 90–97.

Radium treatment is relatively safe if the established principles of technique and dosage are observed. Most of the damage arises through careless implantation of radium near large vessels, nerve trunks, bone or thin-walled viscera, or through neglect of aseptic precautions. Infection is sometimes difficult to avoid especially in the case of uterine cancer where it is not possible to distribute small quantities throughout the growth. This presents a certain disadvantage, especially as compared with roentgen rays.

Radium has its value in the treatment of lip and face epitheliomas and rodent ulcers if the growth has not extended too far, if there is no extensive slough and if the bone is not involved. Comparatively very good results are also reported in the early stages of cancer of the cervix. The results obtained in cancer of the rectum, bladder and associated organs, esophagus, and maxilla are not quite so good. This may be because the technique of radium application in these forms of cancer is very difficult and it is almost impossible to get the required dose homogeneously distributed. In these cases deep roentgen therapy must be considered a superior method, although radium may be of help.

PFAHLER, G. E. Radiation therapy in deep seated malignant disease. *Surg., Gynec. & Obst.*, October, 1925, xli, 443–448.

A review of the results obtained in various European and American clinics leads to the following conclusions: Pre-operative irradiation will devitalize the cancer cell and prevent its transplantation or dissemination. Post-operative irradiation should destroy remaining carcinoma cells. Thorough and skillful treatment with radiation offers most in all stages of carcinoma of the cervix. Recovery in 60 to 80 per cent may be expected if treated in the earliest stages, while less than 1 per cent will recover in late stages. Irradiation is a local method of treatment; the more extensive the disease, the less the chance of recovery.

PILGER, W. The position of deep *x*-ray therapy in gynaecology. *J. Cancer, Dublin*, October, 1924, i, 200–206.

Modern deep roentgen therapy has of late played a dominant rôle among the recognized methods of treatment in gynecology. This is due first to the fact that the methods of modern deep therapy were developed in their present form in the domain of gynecology. Secondly, the anatomical situation of the organs centrally in the pelvis offers very favorable conditions for the converging application of roentgen-ray doses from the surface. Thirdly, operations on the deep organs of the pelvis are always extensive and fraught with much risk, whereas the more conservative deep roentgen therapy, if properly performed, involves no serious risks. The treatment of all kinds of uterine dysfunctions, myomas, chronic inflammatory adnexal conditions, tuberculous affections, dermatoses of the vulva, etc., by means of improved roentgen-ray technique is generally accepted in a good many instances as the treatment of choice. The main field for this treatment lies in the domain of malignant disease.

Some leading clinics in Germany, for example the Erlangen Clinic, have decided to treat all cancers, even operable ones, in the first instance by deep roentgen therapy. Others, however, still consider operation as the method,

using roentgen rays only occasionally and as an auxiliary. The best chances for success with both the operative and roentgen treatments lie no doubt in the early operable cases. An important point in favor of deep roentgen treatment, if there is a place at hand where it can be properly carried out, is its conservatism. A single treatment gives a fair chance to the patient without inflicting harm and leaves the way still open for any other method of treatment. The recovery of the surrounding healthy tissue after the application of not more than one standard dose is a complete one and the conditions for operation are not less favorable than before. The only disadvantage is the loss of some five or six weeks for recovery to be complete. As we gradually pass from operable to inoperable cases we find that roentgen therapy becomes more and more the method of choice until in the late stages it remains the only method available. Where the surgeon is undecided as to the operability of a growth deep roentgen therapy must be considered the method of choice.

PÖHLMANN, CARL. Irradiation of the spleen in bronchial asthma. *München. med. Wchnschr.*, Jan. 9, 1925, lxxii, 57–58.

The radiation was delivered by an Apex III apparatus through 4 mm. Al, 20 x. A second dose was given in four weeks and a further one six to twelve weeks later. Taking into consideration the difficulty in judging the severity of symptoms in asthmatics the general impression is that the radiation therapy was satisfactory. In only 4 cases was there no improvement whatever. In these, retrogression was never observed. The improvement seemed to be proportional to the roentgen sickness produced. No favorable effect of the radiation was observed without the occurrence of roentgen illness. The best result was obtained in those patients in whom the prostration and nausea continued for several days.

It seems not altogether impossible that irradiation of the spleen in these cases has an influence upon the "anaphylactic disposition" of the individual. There is an injury of the splenic function resulting in a lifting of the threshold against antigens tending to produce anaphylaxis.

MISCELLANEOUS

DEBICKI, JOSEF JAXA. Remarks on the present status of roentgenology in veterinary medicine. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, March, 1925, xxxiii, 258–261.

Whereas human roentgenology has made great strides in a relatively short time and assumed a dominating position in medical discipline, the progress of this science in veterinary medicine has been exceedingly meager. The literature of veterinary roentgenology is vanishingly small, consisting in all of about 40 unrelated publications. A textbook of animal roentgenology does not exist.

Animal roentgenology offers an unlimited field for experimental studies, a field which is richer in important biological problems than human roentgenology. Roentgenology truly and fully developed should be a *comparative roentgenology*, a science that does not yet exist.

Because of a lack of sufficient interest in the subject in general, necessary apparatus for roentgenologic studies in veterinary medicine have not been devised, and as a consequence facilities for study do not exist. The author describes briefly a layout of apparatus which he has found useful. One of the essentials is a generator capable of delivering a voltage of at least 170 kv., and a tube capable of standing a momentary load of 100 to 150 ma.

FRAENKEL, MANFRED. Sellheim's sex determination and the relation of his experiments to roentgenologic experience. *Deutsche med. Wchnschr.*, July 3, 1925, li, 1116–1117.

The author has held the view that when benign maladies like myoma, hemorrhages, etc., in aging women are treated with excessive doses for the purpose of rapid results, the result is elimination of follicular development representing one portion of the function of the ovaries, but the endocrine glandular activity is apparently not eliminated but merely injured. This results in a dysfunction which may even lead to psychoses. This view has been strengthened by the recent experimental work of Sellheim who has demonstrated by immunologic methods that the so-called roentgen castration is not an actual castration nor even a mere diminution of endocrine activity, but is actually an alteration in the ovary leading to dysfunction.

This ovarian dysfunction, which often causes epileptiform symptoms in the subjects, has been found to yield to mild stimulative roentgen irradiation of the ovaries. The point emphasized is that the larger doses given in attempting to produce a roentgen castration may produce a serious upset in the endocrine apparatus.

FRICKE, HUGO, and GLASSER, OTTO. A theoretical and experimental study of the small ionization chamber. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, March, 1925, xxxiii, 239–250.

For ionization chambers whose dimensions are small in comparison with the path of the photoelectron in air, the ionization current is

independent of the nature of the chamber and proportional to the chamber volume. This applies to chambers of a volume of about 1 c.c. and for radiations employed in deep therapy. The dependence of the ionization current in a small chamber on the wall material is represented by the equation $I = C_1 + C_2N^3_{eff}$ where C_1 and C_2 are constants and N_{eff} is the effective atomic number of the material of the wall. The graphic representation of this relationship yields a straight line when the cube of the effective atomic number of the material is the abscissa and the corresponding ionization current is the ordinate. The calculation of C_1 and C_2 or the construction of the linear curves for each special quality of radiation can be made from observation of the ionization current in two chambers constructed of different materials (for instance, carbon and magnesium chambers). With the help of these graphs a direct determination can be made of the fraction of total ionization in a small chamber that can be assigned to recoil electrons.

For the definition and measurement of the absolute unit of dosage, "the Röntgen," it is suggested that a small ionization chamber be used constructed of material of the same effective atomic number as atmospheric air (7.69) and of 1 c.c. volume. With such a standard air chamber the erythema dose for relatively hard rays was found to be about 1400 R.

GABRIEL, G. Studies on the use in therapy practice of constant current obtained by introduction of condensers in the Neo-intensiv-reform apparatus. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, March, 1925, xxxiii, 256–257.

By the introduction of condensers and operating the roentgen tube with direct current there was an average reduction in the time for producing a skin unit dose of approximately 10 to 15 per cent. In the case of the deep dose the gain in time is not the same with different tensions but lies between 5 and 6 per cent. There is quite a considerable shift in the quality of radiation produced as shown by measurements with the Glocker analyzer and the Seemann spectrograph. The Glocker analysis shows a distinct shift of the medium rays to hard, and the Seemann spectrograph shows a uniform darkening and a slight shift in radiation quality toward the left.

Some biological experiments were made upon an individual, exposures being made on the abdominal surface, using apparatus with and without condensers. The course of the reaction was followed macroscopically and with the aid of the capillary microscope. The radiation administered was one skin unit dose, 220 kv., 3 ma., 16 min., 0.5 mm. Cu plus 1 mm. Al, field 1 with condensers in place, and field 2 without; field 3 same as field 1. A study of the irradiated areas showed a more uniform erythema and browning where condensers were used.

GOLDHAMER, KARL, and SCHÜLLER, ARTUR. The vertical and horizontal planes of the head. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, March, 1925, xxxiii, 183–190.

For purposes of roentgenologic localization and exact placement for roentgenography, the two new planes are considered useful. These planes are believed to be important primary planes as judged from principles of physiology, and from anthropological and anatomical considerations. These planes also furnish an adequate basis for the judgment of deformities of the base of the skull as illustrated in cases of bathrocephalus, scaphocephalus, and tower skull.

The vertical plane is one running perpendicular to the Perez horizontal at the hindmost point of the rim of the porus acusticus internus (termed "acustion"). Since this vertical usually passes through or very near the basion (i.e. the foremost point of the rim of the occipital foramen in the median sagittal plane), this acustion-basion plane may be regarded as a standard vertical corresponding to the Perez horizontal. These planes have been measured on numerous skulls of children and adults of various races and with various deformities.

After employing the usual craniometric methods for determining these planes, roentgenographic projection methods were employed. The transverse picture was centered opposite a point corresponding to the hindmost point of the inner ear. The basion was located by a mark so that the acustion-basion vertical could be easily found on the roentgenogram. The new horizontal plane was found by constructing a perpendicular to the vertical plane at the acustion.

GROEDEL, FRANZ M. The statistics and possibilities of roentgenologic instruction of German physicians. *München. med. Wchnschr.*, Feb. 20, 1925, lxxii, 310–313.

Roentgenology is not presented in correct or sufficient form but in a most irrational manner, and the physician nowadays finds it possible in only a few places to receive adequate instruction in roentgenology or to become a roentgen specialist.

There should be in each university a roentgen institute independent of the clinics and having the character of a polyclinic. How and

to what extent the established clinics should join with the roentgen institute can be determined by local conditions. An association with the medical polyclinic would be desirable. The central roentgen institute should be a place both for research and instruction. Consequently the number of cases to be handled should be kept low. Instruction should include the physical fundamentals of roentgenology together with anatomy and physiology as seen in the roentgen picture. This is to be followed by instruction in the fundamentals of roentgen therapy and general roentgen diagnosis. Special themes belong to the postgraduate lectures and courses which are offered by the roentgen institute and the various clinics as the need arises. For purposes of research, the facilities of the institute should be available to the various clinics.

HAJÓS, K., and ST. HOFHAUSER. The effect of roentgen-ray irradiation on post mortem autolysis of the liver. *Biochem. Ztschr.*, 1924, cxlvi, 204–207.

The amounts of non-coagulable nitrogen in autolyzed guinea pig liver, immediately after death and twenty-four hours later were 190 and 508 mg. per hundred grams, respectively. The corresponding average values after irradiation ante mortem were 287 and 773. Like results were obtained following irradiation of liver post mortem. These observations lend support to the theory of the participation of the liver in the phenomena following irradiation.